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CONFÉRENCE DES NATIONS UNIES
SUR L'APPLICATION DE LA SCIENCE ET DE LA TECHNIQUE
DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES

Point de l'ordre du jour : A.1.1

Cameroun

PROGRES RECENTS DES TECHNIQUES CARTOGRAPHIQUES AU CAMEROUN

Par M.S. ABAZE,
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Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

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MEMOIRE A-1-1

- Progrès récents des techniques cartographiques au Cameroun - par M.S. ABAZE, adjoint technique géographe - B.P. 157 Yaoundé (Cameroun)

Dès qu'il a disposé des premiers éléments d'une couverture photographique aérienne verticale à l'échelle du 1/50.000 entreprise systématiquement à partir de l'année 1950 - d'ailleurs non encore achevée du fait des difficultés qu'apportent les circonstances atmosphériques au voisinage du golfe de Guinée - le Cameroun s'est efforcé d'obtenir directement et rapidement une carte générale provisoire à l'échelle du 1/200.000 convenable, complète et considérée comme carte semi-régulière, en attendant l'établissement d'une carte de base régulière (1/50.000 ou 1/100.000) qui exige évidemment des délais beaucoup plus longs.

Ce type de carte a été dressé avec le processus suivant :

a) Triangulation photographique par plaques à fentes radiales (T.P.F.R.) montée à l'échelle du 1/100.000, appuyée sur un réseau planimétrique fondamental constitué par un canevas de points astronomiques car une grande partie du terrain ne se prête pas à la triangulation géodésique : les résultats de cette T P F R sont bons car la verticalité de l'axe de prise de vues a bien été maintenue au moment du déclenchement de l'obtureur et les vues elles-mêmes, dont nous a fourni l'Institut Géographique National Français, présentent une régularité de recouvrement stéréoscopique dans les bandes rectilignes bien parallèles entre elles

b) Travail de restitution de caractère variable selon le relief des régions et selon les enseignements acquis par l'expérience et la confrontation des résultats.

Tout d'abord en 1953, pour satisfaire dans des délais courts des usagers pressés, nous avons exécuté au bureau, des fonds planimétriques au 1/200.000 établi par une restitution graphique avec emploi d'un simple pantographe et nous les avons complétés par un tracé de courbes de niveau à l'équidistance de 40 mètres par la méthode des parallaxes stéréoscopiques contrôlée par quelques altitudes recueillies préalablement sur le terrain en même temps que tous les renseignements nécessaires de toponymie et de classement des signes conventionnels et de la végétation.

Les résultats de ce processus ont paru satisfaisants à l'époque mais nous estimons aujourd'hui que les deux feuilles ainsi établies seront à reprendre dans un proche avenir par des procédés photogrammétriques réguliers.

A partir de 1954 nous avons continué à établir au bureau, au pantographe des fonds planimétriques toujours appuyés sur le travail

de T P F R, plus fouillés et à l'échelle du 1/100.000 et seulement pour les régions à relief peu ou moyennement prononcé. Ces fonds ont été complétés par un levé à la planchette des courbes figuratives du relief sur le terrain toujours à l'équidistance de 40 mètres, facilité par l'examen stéréoscopique des photographies et appuyé sur des cotes d'un canevas de détail altimétrique déterminées au fur et à mesure de la progression du topographe en des points aussi caractéristiques que possible du relief, par le procédé des mesures différentielles de pressions appuyées sur des postes barométriques encadrant au plus juste la zone du levé et liés directement à un réseau de nivellement géométrique de précision du type classique, car la solution par visées zénithales n'est applicable ni dans nos régions de savane ni dans nos forêts. Simultanément les éléments de toponymie et de classement des signes conventionnels furent recueillies

Dix sept feuilles ont été ainsi dressées toutes satisfaisantes mais de valeur inégale selon les facilités ou les difficultés (notamment en forêt) de parcours qu'elles comportent.

A partir de 1956, nous avons disposé d'un appareil de restitution de 4e ordre, simple chambre claire stéréoscopique, puis de deux permettant la fourniture de l'image plastique et son basculement, pour le tracé simultané de la planimétrie et des courbes de niveau toujours à l'équidistance de 40 m.

Nous avons pu ainsi dresser cinq bonnes feuilles correspondant à des régions de relief très prononcé, de parcours très difficile et parfois de végétation très dense.

Ce travail de restitution a nécessité l'exécution préalable au bureau du canevas planimétrique de restitution au 1/100 000 obtenu comme ci-dessus, par un travail de T P F R puis, le recueil sur le terrain d'éléments de préparation altimétrique des photographies, par mesures barométriques comme il est dit ci-dessus, et des éléments de toponymie, de classement des signes conventionnels et des distinctions de la végétation sur un calque adapté aux épreuves photographiques de numéro pair. La préparation altimétrique fut effectuée d'abord à quatre points altimétriques régulièrement disposés aux angles de tous les couples puis réduite à la préparation d'un minimum de couples facilement accessibles, restitués en priorité et servant d'appui à la restitution d'autres dans lesquels on ne s'était attaché qu'à coter des points caractéristiques du réseau hydrographique et des lignes de crête et enfin encore plus réduite, lorsque nous avons pu utiliser notamment pour une région de grande forêt, les résultats de l'aérocheminement de la couverture aérienne. Pour ceci, comme pour bien d'autres opérations décrites ci-dessus, nous avons bénéficié de l'appui des personnels et des matériels de l'Institut Géographique National Français (I.G.N.) auquel nous continuons à confier la poursuite de l'oeuvre cartographique au Cameroun

Simultanément cet Institut dressait des coupures régulières au 1/50.000 ou au 1/100.000 avec courbes à l'équidistance normale de 20 mètres et intercalaires à 10 mètres sur notre demande pour nos régions essentielles. Evidemment nous avons attendu pour dresser les feuilles au 1/200.000 correspondantes de recevoir ces coupures et nous avons rédigé ensuite à partir de celles-ci dans nos ateliers, par gé-

néralisation et réduction photographique, douze feuilles d'une carte régulière au 1/200.000.

Pour achever la carte générale au 1/200.000 du territoire de la République Fédérale, il nous reste à lever la surface correspondant environ à huit feuilles pour lesquelles nous ne disposons malgré des tentatives de prise de vues systématiquement repétées depuis des années, que de fragments de couverture que d'ailleurs, nous exploitons au fur et à mesure pour améliorer des croquis provisoires au 1/200.000 dressés antérieurement à partir de renseignements d'origines diverses.

Nous espérons que les procédés de préparation aéréoportés, qui seront mis en application par l'I.G.N. au Cameroun en fin d'année 1962 pour le levé photogrammétrique, à des échelles égales ou supérieures au 1/50.000, de région d'intérêt économique pressant, nous permettront de raccourcir les délais d'établissement des huit feuilles manquantes de la carte au 1/200.000 et, ceci, dès que les escadrilles spécialisées, auxquelles nous faisons appel, auront rencontré les circonstances favorables pour achever la couverture photographique de notre territoire.

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UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.1

Philippines

PHILIPPINE NUMERICAL PHOTOGRAMMETRIC CADASTRE

By G.T. MARZAN
G. UMADHAY

and T.C. JIMENEZ,
Geodetic engineers-photogrammetrists
under the supervision of
NICANOR G. JORGE,
Director of Lands

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

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PHILIPPINE NUMERICAL PHOTOGRAMMETRIC CADASTRE

By C.T. Marzan, C. Umadhay, & T.C. Jimenez, geodetic engineers-photogrammetrists
under the supervision of
Nicanor G. Jorge, Director of Lands

1 The Cadastral System in the Philippines. Land registration in the Philippines is based on the Torrens System which originated in Australia and presently used in the State of Massachusetts, U.S.A. The title to the land rather than the muniment of ownership is registered in a registry of property. The underlying principle of the Torrens System is the indefeasibility of titles. Once a certificate of title is issued by offices of registry on order of our courts after due hearing, the technical descriptions of the land for which the title was issued become fixed and inalterable. This principle is necessary for the permanency of land ownership. The title issued contains among others: (1) the directions and lengths of boundary lines, (2) the adjoining lots or owners, (3) the direction and distance of corner one of each lot to a location or conservation monument, and (4) the area of the land. With these descriptions, the identity of the property - its location and orientation on the ground, its size and shape, and its relation to other lots or property - becomes definite.

2 The Philippines, though consisting of several thousands of islands, is subdivided into provinces. Each province in turn is subdivided into municipalities. All the unregistered land in a municipality may be the subject of mass registration. When in the opinion of the President of the Philippines the public interests require that the titles to the lands in that municipality be settled and adjudicated, he orders our Director of Lands to execute a cadastral survey. Upon the completion of the survey the maps or plans of the cadastral survey and the technical descriptions of all lands subject to registration are forwarded to the Court for the settlement and adjudication of titles.

3 The Present Method of Cadastral Survey. In the technical descriptions of a piece of land contained in our titles, the directions of boundary lines are given to the nearest minute of arc, the lengths to the nearest centimeter, and the area of each lot to the nearest square meter. These data are all derived by computation from ground corner coordinates. We also require in the position of a lot corner a precision of ± 30 cm. in our agricultural regions and ± 10 cm. in our urban areas. Towards these end results we execute our cadastral surveys. Ours, therefore, is a purely numerical cadastre.

4 Once an order of a cadastral survey is issued by the President of the Philippines, the following are the steps we take:

(a) 1. Notification of the survey - The cadastral survey is published in our Official Gazette, notices are posted in the location of the land, and individual notices are sent to owners or claimants of landed properties in the municipality These notifications are important so that everybody having interests in any property is afforded the chance to protest his rights. Since the underlying principle

of the Torrens System is the permanency of land titles, whatever descriptions of the land are placed in the title should be the result of the agreement of all concerned or the result of what is just under the circumstances.

(b) 2. Control survey for the project - Only a small portion of the Philippines is covered by either 2nd order or 3rd order triangulation controls. When there is a cadastral survey of a municipality, therefore, we run a control traverse survey for each project, connecting it, where possible, to the nearest triangulation stations or to stations of traverse control for previous cadastral projects. The precision of control traverses depends on the area of the project. We have been using transits of American manufacture. After the last war we have also used direction theodolites and repeating theodolites of European manufacture. For measuring distances, the steel tapes we use are of American manufacture. We are also using the tellurometer and the subtense bar.

(c) 3. Lot Sketching and Identification - Owners or claimants are made to indicate on the ground their boundary corners and together with the adjoining claimants to agree on the common boundaries. Simultaneously, agreements are sketched by our fieldmen producing what we call lot sketches. Sketching are made by means of a plane table and are tied to control traverses. This, then, is one of the more tedious parts of the work. Besides showing the layout of all the lots, the lot sketches serve as the guide for our final lot survey and plotting.

(d) 4. Final lot survey - In that part of the project where lot sketching has been completed, we then execute the final lot survey. Traverses are run from stations of traverses of higher order covering all lot corners.

(e) 5. Computations and Maps Preparation - After the final lot survey, the tremendous amount of work of computing the coordinates of corners and subsequently the directions and distances of boundary lines and areas of lots is undertaken. At the same time the lots are plotted on the final cadastral maps of 1' quadrangle at the scale of from 1:1000 to 1:4000. All these records are subsequently prepared for submission to our Courts.

5 Cadastral surveys as described above started in the Philippines in 1909. To date about 10.5 million hectares of the total 30 million hectares area of our country had been surveyed. Based on the statistics of cadastral survey projects already completed we have averaged thus far 200,000 hectares per year. There remains approximately 19.5 million hectares and apparently if we are to continue at the same rate we can hope to finish the survey of our country only in at least another century.

6 The Photogrammetric Method. It is no mere coincidence that development in areas of our country where titles have been cleared has been faster. The issuance of land titles accelerates the economic development of an area. Since cadastral survey is a prerequisite to title issuance, by the rate we execute cadastral surveys by that much only do we bolster economic development. Our government, therefore, has turned to photogrammetry - to find out whether with this method we can attain (1) the desired acceleration of cadastral survey, (2) a decrease in the cost of cadastral survey, and (3) a better assurance of the accuracy of the results, which is very important because of the requirement that technical descriptions are permanent and inalterable.

7 In 1938, we started to undertake the cadastral survey of the Province of Bulacan, as a pilot photogrammetric project. The project has an area of 149,000 hectares involving 15 municipalities and approximately 61,000 lots. After our President issued the necessary order for cadastral survey, negotiations were conducted for the acquisition of photogrammetric instruments and equipment resulting

in our now having two first order stereoplotting machines equipped with electronic coordinate registering devices and card punching machines, and two automatic aerial film cameras. At the beginning of our project we had also at our disposal an aerial plate camera. Recently we acquired a rectifier-enlarger having a lens of high resolving power. Together with an electronic data processing machine, these equipment form the bulk of our photogrammetric installation.

8 The project is a joint undertaking of the Philippine Air Force which takes charge of the aerial photography and the Bureau of Lands which takes charge of the photogrammetric work including the requisite ground work. More detailedly, this division of work is as follows:

(a) Philippine Air Force: (a) flight planning, (b) taking of aerial photography, and (c) photographic processing. Bureau of Lands: (a) assisting in flight planning, (b) preparing notification of survey and lot sketching, (c) monumenting and signalization of lot corners, (d) establishing photo control points, (e) aerial triangulation, (f) stereoplotting and stereocoordinating, (g) transforming coordinates and adjustments, and (h) final lot computations and maps preparations.

9 We shall now discuss how we have adopted photogrammetry to our local conditions.

10 1. Aerial Photography. The choice of the scale of our photography has been guided by practical considerations rather than by the size of our corner monuments or by the precision we require of the position of a lot corner although the latter has not been sacrificed. We are using corner monuments with a diameter of 15 cms. which requires the scale to be 1:6000. With our requirement of $\pm$ 30 cm. in the position of a corner and considering 10μ as the attainable overall mean square error in the plane of the negative for the whole photogrammetric procedure, this scale is acceptable. But, is this the most economical scale? Before we started photography in the project, we had test flights using different flying heights over a test area where we had placed different sizes of signals. The test flights showed that the 15 cm. signals were still visible at a photo scale of 1:12,500 and some were even identifiable at 1:15,000 photo scale. This perhaps is attributed to the very high resolving power of the camera lens and also to the good contrast between the white signals and the surrounding area. Based on the experience in the test flights, we decided that the photography for the final survey flight to be taken by the plate camera with wide angle lens will be 1:8000 and that to be taken by the film camera with a normal angle lens 1:7500. Both will have the 60% forward overlap and a 30% lateral overlap. These are the scales of photography we took in the first area of Bulacan. In the other areas, we subsequently used the plate camera for photography at the scale of 1:12,500.

11 It was also first decided that our flight planning was to be done on available 1:50,000 US Army Map Service maps. We found that these maps were outdated and that some planimetric features were not correctly represented so they were not suitable for the flight plans for the final survey flight. Consequently another photography at the smaller scale of 1:15,400 which we called preliminary photography was taken of each area. This was assembled into semi-controlled mosaics and then reproduced to a scale of 1:25,000. On the resulting reproduced mosaic, the flight plans for the final survey flight were drawn.

12 2. Lot Identification On Photographic Enlargements. The preliminary photography served a second purpose. We divided each photograph into quadrants and each quadrant was enlarged to a scale of 1:4,000. These enlargements, mounted on a hard board, were used for our lot sketching. Boundary corners agreed upon by the owners were simply located and pricked on the enlargements. This made lot sketching much more convenient and increased the rate of work four times. What was even more heartening was the psychological effect on the owners when they saw

that the details of the ground definitely corresponded with those on the photographs. The lot sketches attained more meaning than mere points and connecting lines representing their properties. These lot sketching enlargements became the guide for stereoplotting insuring the coverage of all points visible in the stereoplotting machine. We must point out that before the lot sketching, notification of claimants were made in the usual manner.

13 3. Signalization. One question which we were not able to resolve during the test flights was that of signalization. Since one frequent source of error is the misidentification of points, signalization of corner monuments is important. But what should the minimum amount of signalization be that will give no misidentification or at least minimize it? In order to answer this, the first area we photographed was divided into two sectors. In one sector we signalized corner monuments by whitewashing the top with carbide waste so that they were simply white spots 15 cm. in diameter. In the other sector we signalized monuments by whitewashing the top and painting cross-bars of 15 cm. width and 70 cm. length radiating at a distance of 80 cm. from the corner monument. We signalized without the cross bars because usually boundary corners in our agricultural areas were also intersection of ricefield dikes which, we reasoned, would make them easily identifiable. However, in the actual stereoplotting we found that there were many other dike intersections that were not cornersat all and white spots on them sometimes led to misidentification. In that area where we used cross bars we were able to identify almost all corners easily. In the subsequent areas of the project, therefore, corner monuments were signalized with cross bars.

14 4. Photo control point survey. Each model was provided with at least four control points, either surveyed on the ground or by aerial triangulation. We had to select photo control points after the photography. The Philippine Air Force has not had experience in the exacting requirements of cadastral survey flights so that it was not possible to preselect points and employ pinpoint navigation. Selection of control points in the common overlap of models was made in the office from the diapositives using mirror stereoscopes with 8x magnification. The layout of the photography allowed the formation of five blocks for aerial triangulation to reduce ground survey of points. For models not included in the blocks full ground control were provided. Simultaneously with the other ground preparation, field parties were extending our triangulation work until there were stations every 2.5 to 5 ms. Traverses run for the survey of photo control points were connected to triangulation stations or to traverses of higher order. Elevations of points were determined by running level lines or simultaneously with the traverses.

15 5. Aerial Triangulation. Strips were all provided with full ground control in the first and end models. In addition, the first and last strips of each block were also provided with ground control at the outer edges. Since our stereoplotting machines are first order ones, aerial triangulation was done continuously along a strip with the base-in base-out method.

16 6. Stereocompilation. Models with full ground control were immediately plotted after the ground coordinates of the photo control points were computed. Both relative and absolute orientations were done with the numerical method. In the process of stereocoordinating, which is done twice for each model, machine coordinates of points were automatically punched on cards, and in stereoplotting, points were directly plotted on map sheets. We had to maintain two shifts with two persons per shift in each machine - an operator and a cartographer assisting him on the plotting table.

17 7. Transformation and adjustments. Transformation of machine coordinates into ground coordinates was done either with the Helmert or Affine transformation. For the adjustment of three blocks of aerial triangulation, a new method called

the "Sequential Least Squares Affine Adjustment" (or SELSAFF) was developed by one of our photogrammetrists. We are now researching on another method of adjustment for the other two blocks which might be less cumbersome than the first method. To all these new procedures, also, we dovetail our adjustment of previously approved surveys that are scattered among lots undergoing survey so that all coordinates are transformed into one uniform system. This phase we have termed "old surveys adjustment." All these computations are done by means of an electronic data processing machine (EDPM).

18 8. Final lot computations and Map Preparation. After points have had their transformed ground coordinates, computations of the directions and lengths of boundary lines, the areas of lots and the directions and lengths of the line from a location or conservation monument to corner one of each lot followed. These maps are finalized, inked, and prepared for the signature and approval of the Director of Lands. Records will then be ready for submittal to the Courts for the land registration proceedings.

19 9. Personnel Requirements. Photogrammetry being a new method in our cadastral survey, we had to take stock of the availability of the required technical personnel and their training requirements in the different work operations of the project. The University of the Philippines has been offering the degree course in geodetic engineering since 1937 including theoretical subjects in photogrammetry. From the pool of graduate geodetic engineers we drew the technical personnel for the project including our incumbent Director of Lands who was sent in 1952 on an MSA grant to the US and Europe to make studies and observations in photogrammetry, geodesy, and cartography and eight Colombo Plan scholars who took up the diploma course in photogrammetry at the University College London from 1953 thru 1955. At the beginning of the project, however, two European photogrammetric firms made available two of their photogrammetrists to help us out in the initial work stages as no one in our country has had a considerable experience in such a large undertaking. We retained one of them as a technical consultant who together with our engineers trained abroad formed the working staff that guided, and trained other personnel for, the project. During the progress of the project, we were recipients of fellowships and scholarships abroad, such as, from the Netherlands, Australia, the UN FAO, West Germany, Switzerland, Italy, and France. Thus we have taken advantage of the offers of the more advanced countries of the world to assist the developing areas. Their readiness to render such assistance is a great source of encouragement.

20 Advantages of the Photogrammetric Method over the Conventional Ground Method. In the beginning of this paper we gave a triple purpose for our adoption of photogrammetry, namely, 1) accelerated rate of survey, 2) lower costs, and 3) more confidence in the accuracy of results.

21 On the rate of doing the work, our overall performance is not spectacular. There are observations, even, that were the project executed by the conventional ground method we would now have accomplished more. But this being a pilot project we have been beset and delayed by all sorts of problems - technical, administrative, and other practical considerations. Yet it seems noteworthy to state that if we are able to stick to our timetable now we hope to finish the project by this year. This will be a record of completing 15 municipalities in four years where for the conventional ground method we spend from three to five years to complete a cadastral survey of one municipality alone.

22 As to the unit cost, to date, our computations for that part we have completed show that we are getting a unit cost of P22.01 per lot or approximately P9.00 per hectare. For our surveys on the conventional method we are, at present, averaging

P35.00 per cadastral lot or approximately P12.00 per hectare. Photogrammetry has, therefore, proved to be cheaper. When the procedures of the work will be systematised further as a result of our experiences in the project, there is reason to believe that this unit cost will even be lower.

23 The most encouraging part of the work is the accuracy we have obtained. Of the models we have so far completed we are obtaining an average mean square error of ± 23 cm. in the position of a point. There are, however, a number of big discrepancies we have discovered between positions of points obtained by the photogrammetric method and positions of the same points from conventional ground surveys of several years ago. Studies we have made attribute this to the precision of the previous surveys. This is one of the technical problems that considerably delays the project. One distinct advantage of photogrammetry is the fact that one can prescribe checks at the various stages of the work that insure the maintenance of the overall precision of the work. Such checks are not very convenient with the conventional ground method. Also the automation of several phases of the work greatly minimizes chances of human errors. All these cannot but lead to a greater confidence in the accuracy of the result and, therefore, a firmer foundation for our Torrens System of land registration.

24 Besides these advantages in cadastral surveys, photogrammetry offers more far-reaching benefits not obtainable with the conventional method. The photographs can also be utilized in the compilation of topographic maps vital to the socio-economic development of the country. Furthermore, photographs contain an unlimited wealth of information that can be analyzed through photo-interpretation for various requirements of forestry, soil conservation, geology and others.

25 Favorable Effects of Adoption of Photogrammetry on Socio-Economic Development of the Country. The Philippines is basically an agricultural country. Agriculture will for many years to come be the base of our economic progress. The survey of a property and the consequent issuance of the title to it obtains for the owner the security of his possessions. Delimitations of land boundaries, therefore, become a necessary condition to a well ordered society. In such an atmosphere of settled conditions in our communities there arises a faster tempo of economic activity. As more landowners obtain their titles, lending institutions have brisker businesses because more properties will be available as collaterals for loans that may be needed in agricultural, commercial or industrial undertakings. Idle capital are therefore released for productive enterprises. A speedy survey of the country also becomes in effect a faster assessment of the land resources of the country resulting in (1) a more accurate assessment of the sources of revenues for the government, which when channeled to the different development programs of the country leads to more improved facilities and conditions of living for all citizens; (2) the utilization of every available piece of land to production which together with the intense application of scientific methods in agriculture will lead to a greater agricultural production and thus, to national self-sufficiency.

26 Proposed Long Range Program of Photogrammetric Survey. As a result of our experience in the Bulacan Pilot Photogrammetric Cadastral Project, our Director of Lands has drawn up a long range plan for a nationwide survey of the Philippines. He proposes a 15-year period within which to finish the remaining two-thirds of the country's area. With this plan we hope to achieve a unit cost of less than P6.00 per hectare. To implement this program, we are recommending to our Congress the passage of a bill appropriating P25 million for this purpose. We are also looking forward to possible aid from the UN Special Fund which we are negotiating through the local UNTAB representative.

27 Thus we have shown how we are utilizing science and technology in our cadastral surveys. And in proposing to do it in a nationwide scale we are striking at the heart of our country's socio-economic program of alleviating the living conditions of the masses of our people and securing continued prosperity for them, their children and their children's children.

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DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES

Point de l'ordre du jour : A.5.1

Cameroun

POLITIQUE D'EXPLOITATION DES RESSOURCES MINERALES AU CAMEROUN

Par C. CHATUE-KAMGA,
Directeur des Mines
et de la Géologie

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

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2. Les mémoires choisis pour être présentés en séance spéciale pourront être obtenus à la Conférence dans l'une seulement de ces langues officielles.

3. Les résumés qui ont été rédigés pour tous les mémoires par les auteurs de ceux-ci pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

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I- POLITIQUE D'EXPLOITATION DES RESSOURCES MINERALES

I) - POLITIQUE GENERALE.- L'industrie minière représente dans la République Fédérale du Cameroun, une faible part de l'activité industrielle du pays. La valeur totale des produits extraits annuellement est inférieure à cinquante millions de francs C.F.A., ce qui représente environ le chiffre d'affaires annuel d'une scierie de moyenne importance. Les raisons qui expliquent cet état de chose peuvent être trouvées en partie dans le fait que les régions du Cameroun où la présence de gisements minéraux serait le plus souhaitable, se trouvent couvertes par la forêt et sont restées longtemps fermées à la prospection minière qui n'a réellement disposé de moyens d'investigations puissants qu'au cours des dernières décades. Aussi, si la production minière est encore infime, des sommes très importantes sont par-contre investies annuellement tant par l'Etat que par des organismes privés, dans les études géologiques, la prospection et la recherche minière et les résultats de ces activités auront certainement des conséquences heureuses, au cours des prochaines décades, sur l'économie du pays. Le Gouvernement est par ailleurs conscient de l'importance considérable de ces conséquences. Aussi a-t-il adopté de nombreuses dispositions pour encourager le développement des exploitations minières. Parmi ces dispositions on peut citer notamment :

1°) L'établissement de la carte géologique par l'Etat.

La carte géologique, outil de base pour la prospection et la recherche minière, présente un intérêt certain. Pour être valable, elle doit être faite pour l'ensemble du pays, tout au moins pour les échelles inférieures au 1/200 000è.

Par ailleurs son établissement nécessite des fonds importants qu'une entreprise privée ne pourrait investir sans grever lourdement le prix de revient de l'exploitation du minerai à découvrir. C'est pourquoi l'Etat a pris à sa charge le financement et l'exécution de la carte géologique. Le levé de la carte géologique commencé en 1949 d'abord à l'échelle du millionième puis poursuivi à l'échelle de 1/500 000è sera achevé pour l'ensemble de la Fédération en 1964. L'achèvement de ce travail fournira ainsi un document de base de valeur inestimable à toute personne qui s'intéresse à la prospection minière au Cameroun. Par ailleurs le levé de la carte géologique a permis la découverte de nombreux indices dont l'étude a été parfois décevante (cuivre, diamant, etc...), parfois encourageante (bauxite, fer, disthène).

2°) Droit à titre d'exploitation en cas de découverte d'un gisement exploitable.

La recherche et la prospection minière présentent non seulement des aléas plus importants, mais encore nécessitent des fonds plus considérables dans un pays comme le nôtre où le développement industriel n'a pas encore atteint son niveau normal. Aussi a-t-il été nécessaire, pour amoindrir cet inconvénient et encourager la venue des chercheurs, de leur garantir l'obtention d'un titre d'exploitation dans le cas où ils découvriraient un gisement exploitable. Cette disposition est incluse à l'article 11 de la loi minière du 31/12/1960.

3°) Encouragement des exploitations minières par un allègement des impôts et participation de l'Etat au capital de certaines sociétés.

L'industrie minière des pays en voie de développement, si florissante soit-elle à un moment donné, est soumise aux fluctuations désordonnées des cours et des débouchés mondiaux. Le marché intérieur n'absorbant généralement qu'une très faible proportion de la production, il n'existe pour l'Etat que deux moyens efficaces, pour aider l'industrie minière en difficulté : c'est l'allègement des impôts existants et pour certaines entreprises dont l'activité revêt une importance sociale et économique la participation de l'Etat au capital peut être envisagée.

4°) L'encouragement de la venue des capitaux étrangers par une politique des investissements attrayante et stabilisant les régimes juridiques et fiscaux.

Cette politique des investissements a été déterminée par la loi 60/64 du 27 Juin 1960 portant code des investissements pour la généralité des entreprises et par les ordonnances du 31 Mars 1962 et du 21 Juin 1962 pour les sociétés se livrant à la recherche et l'exploitation des hydrocarbures. Une analyse succincte de ces textes est faite au chapitre de la fiscalité.

II - DIRECTION DES MINES

Pour veiller à l'exécution de la politique minière du Gouvernement, pour assurer l'exécution des travaux de géologie et de recherches qui relèvent de l'Etat, pour promouvoir la recherche et l'exploitation des Mines par des personnes privées, une Direction des Mines et de la Géologie a été créée. Cet organisme a à la tête un Directeur qui relève directement de l'autorité du Ministère chargé des Mines. La Direction des Mines et de la Géologie comprend une section des Mines et une section Géologique.

La section des Mines, en plus d'attributions extra-minières telles que le contrôle des appareils à vapeur, des explosifs, des carrières, etc... s'occupe notamment de l'application des textes miniers et de la conservation de la propriété minière.

La section Géologique a comme attributions, l'exécution de la carte géologique et la réalisation des travaux de prospection effectués par l'Etat. Elle dispose à cet effet d'un Laboratoire, d'un Musée, d'un Bureau de Dessin et de Cartographie, d'une Bibliothèque et d'un Atelier de réparations des véhicules.

Le personnel d'encadrement comprend actuellement outre le Directeur, un Sous-Directeur, un Ingénieur-Géologue, un Ingénieur des Mines, un Ingénieur-Chimiste.

L'effectif total (employés, ouvriers et manoeuvres) est de l'ordre de cinquante.

III - EXPLOITATIONS MINIERES

Les exploitations minières existant actuellement au Cameroun sont celles de la Cassitérite et de l'Or.

Etain .- Le gisement de cassitérite de Mayo-Darlé a été mis en exploitation par la société des étains du Cameroun (S.E.C.) depuis l'année 1933. L'épuisement du gisement et les résultats négatifs des travaux de prospection et de recherches effectués ces dernières années pour reconstituer les réserves ont amené la S.E.C. à céder cette exploitation à une nouvelle société qui se propose d'exploiter les taillings avec des frais généraux moins élevés. Cette dernière phase de l'exploitation permettra la récupération annuelle de 40 à 50 tonnes de produits marchands et aura une durée de plusieurs années.

O r .- La production d'or du Cameroun est de 15 Kg. en moyenne par an. Seule une Compagnie à Détaré-Oya exporte régulièrement de l'or Sa production provient essentiellement de la collecte de l'or auprès des tâcherons travaillant sur les permis de la société.

Recherches Minières .- La recherche minière est assez active au Cameroun. En effet, cette activité est soit la conséquence des travaux de prospection générale et de levé de la carte géologique, soit l'initiative de sociétés privées attirées par les possibilités minières de notre pays. Parmi les travaux de prospection et de recherches effectués à la suite du levé de carte géologique il faut citer les recherches pour cuivre, diamant, disthène, fer, aluminium.

Recherches pour cuivre .- Ces travaux entrepris par une entreprise privée dans la région de Tiffel au Nord-Ouest de Garoua ont permis de déterminer que les filons minéralisés étaient contrôlés pétrographiquement par des roches acides. Malheureusement la faible teneur du minerai et le peu d'extension des filons rendent négatif le résultat des travaux Cependant au cours des travaux d'autres indices ont été mis à jour sur le secteur TIFFEL-GOUTCHOUMI et des travaux sont entrepris sur ces indices.

Recherches pour diamant .- Ont été réalisées au cours des années 58 à 61 à la suite du levé de la carte géologique dans l'Adamaoua. Les formations étudiées sont celles de M'Béré et du Djerem. Malgré la découverte de quelques indices intéressants le résultat global des travaux est négatif et ceux-ci ont été abandonnés.

Recherches de disthène - Un organisme privé est titulaire d'un permis d'exploitation valable pour le disthène dans la région d'Edéa. Les études effectuées ont montré qu'il existe dans cette région en amont de la rivière Nyiba un petit gisement de cette substance qui pourrait donner lieu à une petite exploitation. Des essais de ce produit réfractaire sont actuellement en cours.

Recherches pour fer .- Le Cameroun possède un gisement de fer dans la région de Kribi. Ce gisement est couvert par des titres miniers. Les réserves de ce gisement sont évaluées à 150 millions de tonnes d'un minerai constitué pour la plus grande partie de quartzites ferrugineux à 35 % de fer. Malgré la teneur en fer relativement faible, il est possible cependant que ce gisement soit mis en exploitation un jour grâce aux conditions faciles d'évacuation qu'il présente.

Recherches pour aluminium .- Deux gisements de bauxites sont connus au Cameroun et font l'objet d'études actives. Ce sont les gisements de Fongo-Tongo dans le Département de la Menoua et le gisement de Minim-Martap Ngaoundal dans le Département de l'Adamaoua.

Le gisement de Fongo-Tongo est estimé à 40 millions de tonnes d'un minerai à environ 45 % d'alumine et 2 % de silice soluble (teneur après criblage). Des essais industriels de ce minerai ont été effectués.

Le gisement de Minim-Martap est situé à 120 Km. au Sud-Ouest de Ngaoundéré, au Nord de la dépression du DJEREM dans le bassin de Haut-Maouor. Celui du massif de Ngaoundal est situé à environ 30 Km. au Sud-Est du précédent.

Dans ces deux secteurs des plateaux coiffés d'une carapace bauxitique ont été reconnus et étudiés par fonçage de puits implantés systématiquement. Dans l'ensemble les plateaux étudiés dans le périmètre de Minim-Martap montrent une carapace bauxitique d'une épaisseur variable avec de bonnes teneurs en alumine. Les résultats obtenus dans le secteur de Ngaoundal sont plus inégaux. L'ensemble des recherches sur ces gisements montre que la carapace bauxitique a en moyenne une puissance variant entre 8 et 9 mètres. Les teneurs moyennes sont de l'ordre de 43 % d'alumine et de moins de 3,4 % de silice totale.

Près de 5.000 hectares ont été reconnus et ont permis d'estimer que pour l'ensemble des deux gisements les réserves s'élèvent à plus d'un milliard de tonnes de bauxites. Pour le seul gisement du Ngaoundal une étude détaillée a permis d'estimer les réserves à 90 millions de tonnes d'une bauxite à 41,7 % d'alumine et 1,4 % de silice totale, la puissance moyenne minéralisée étant de 11,2 m.

Recherches de pétrole .- Une société de recherche de Pétrole s'intéresse au bassin sédimentaire de Douala depuis 10 ans. Un petit gisement de gaz a été découvert mais le marché intérieur actuel ne permet pour le moment pas la mise en exploitation de ce gisement par l'installation d'une usine de dégazolinage. Les travaux de recherches se poursuivent cependant et la société a l'intention d'étendre dans les jours à venir ses travaux au large des côtes du Cameroun.

IV - LEGISLATION MINIERE

La législation minière en vigueur est celle fixée par la loi minière du 31 Décembre 1960. Ce texte a été adopté avant la réunification de deux Camerouns et ne se trouve par conséquent applicable qu'au Cameroun-Oriental. La réglementation minière applicable au Cameroun Occidental dérive de celle de la Nigéria. Vu les conséquences économiques et sociales pour l'ensemble du pays qui découlent généralement des affaires minières, celles-ci ont été portées à la compétence du Gouvernement Fédéral par la Constitution du 1er/9/61. Si bien qu'un texte unique refondant les réglementations des deux Etats de la fédération devra être adopté à l'échelon Fédéral. Ce texte actuellement en préparation, n'apportera pas de grandes modifications aux réglementations actuelles dont les différences ne sont par ailleurs pas importantes.

La législation minière valable au Cameroun Oriental dérive de celle de l'ancienne Administration de Tutelle. Toutefois si les principes de cette législation ont été maintenus, la nouvelle loi minière a apporté un grand nombre de simplifications aux textes existant sous l'ancien régime.

Les principes de la législation minière applicable au Cameroun sont les suivants :

- 1°) Le droit à recherche ou exploitation minière est distinct de la propriété du sol. Alors que l'article 3 de la loi minière du 31/12/60 dispose que les carrières sont réputées ne pas être séparés de la propriété du sol et qu'elle en suivent les conditions, par contre, pour ce qui concerne les substances concessibles l'article 4 de la même loi prévoit que le droit de prospection, le droit de recherches minières et le droit d'exploitation ne peuvent être acquis qu'en vertu d'une autorisation de prospection, d'un permis de recherches minières, d'un permis d'exploitation ou d'une concession minière.

La défense de cette disposition fondamentale ne paraît pas indispensable ici, si l'on admet que le morcellement de la propriété du sol tel qu'il existe au Cameroun génerait considérablement la recherche minière effectuée généralement sur de vastes étendues et l'exploitation des Mines, dans le cas où les exploitants miniers seraient soumis au bon vouloir des propriétaires du sol.

Il faut signaler par ailleurs que la législation minière n'a pas prévu une propriété minière proprement dite mais seulement un droit exclusif de recherches ou d'exploitation des substances classées dans la catégorie des substances concessibles.

- 2°) La Mine est définie par la nature du produit exploité et non par la nature de l'exploitation. En effet, la distinction entre les produits de carrières relevant de la propriété du sol et les produits

de mines relevant de la réglementation minière est déterminée par l'article deux de la loi minière. Cet article définit les produits de carrière qui sont les produits utilisés comme matériaux de construction et d'amendement et les tourbières. Sont classés comme produits de mines ou substances concessibles, toutes les substances non classées dans les carrières.

3°) La durée des titres miniers est limitée. Alors que dans certaines réglementations étrangères la durée des titres d'exploitation minière est illimitée, la réglementation minière du Cameroun a limitée la durée de l'autorisation de prospection, du permis de recherches et du permis d'exploitation à quatre ans tandis que celle de la concession est fixée à 75 ans. Le renouvellement de ces titres miniers est par ailleurs possible si le titulaire a rempli certaines obligations prévues par la réglementation minière, notamment celle du maintien d'une activité suffisante sur le titre minier pendant la période de validité.

4°) Les titulaires de titres miniers ont droit à permis d'exploitation s'ils rapportent la preuve de l'existence d'un gisement économiquement exploitable à l'intérieur de leur titre minier.

Vu les aléas considérables de la recherche et les investissements très importants qu'elle nécessite, dans les pays comme le nôtre où le développement économique n'est pas encore suffisant, il est apparu utile de garantir à ceux qui s'intéressent à nos affaires et désirent investir des fonds dans notre pays, qu'ils ne seront pas frustrés du résultat de leur effort au moment de la mise en exploitation de leur découverte.

Fondée sur ces quatre principes la réglementation minière en vigueur a prévu une autorisation de prospection et trois titres miniers exclusifs. L'autorisation de prospection n'est pas exclusive; elle est valable pour une ou plusieurs substances et peut s'étendre sur un ou plusieurs départements.

Le permis de recherche est accordé non pas automatiquement au premier demandeur comme le prévoyait les textes de l'ancien régime, mais à celui qui est le plus digne de le détenir tant par ses capacités techniques et financières que par sa valeur morale. Si le principe de cette attribution discrétionnaire du permis de recherche supprime la liberté totale en ce qui concerne l'octroi du permis, par contre une fois que le permis est accordé, la réglementation en vigueur prévoit le renouvellement de tous les titres miniers et leur transformation en titres d'exploitation d'une façon automatique et de droit d'une part si le titulaire a effectué un minimum de travaux obligatoires, d'autre part s'il y a gisement exploitable.

Enfin, pour éviter l'accaparement et pour obliger les exploitants miniers à maintenir sur leurs titres miniers une activité suffisante, un minimum de travaux obligatoires est imposé, une réduction de périmètre est prévue pour les permis de recherches d'hydrocarbures et une taxe proportionnelle à la surface est perçue.

FISCALITE MINIERE

Les exploitants miniers, à l'exception des sociétés qui se livrent à la recherche et à l'exploitation des hydrocarbures, sont soumis aux impôts et taxes du régime commun et aux impôts, taxes et redevances minières proprement dites.

Les impôts du régime commun comprennent :

- 1°) l'impôt sur les bénéfices industriels et commerciaux (B.I.C.) dont le taux est de 20 % et auquel il faut ajouter les centimes additionnels 2,5 %.

- 2°) l'impôt sur le revenu des valeurs mobilières perçu sur les dividendes distribuées dont le taux est 7 %;

- 3°) la taxe de transaction sur le chiffre d'affaires (5 % du chiffre d'affaires);

- 4°) la taxe sur le capital;

- 5°) les droits d'entrée qui comprennent le droit fiscal et les droits de douanes;

- 6°) les droits de sortie;

- 7°) un grand nombre de petits impôts dont le montant n'atteint pas 2 % des bénéfices.

Les taxes et redevances minières comprennent :

- 1°) les droits fixes de délivrances et de renouvellement de titres miniers qui sont pour la plupart infimes;

- 2°) la redevance superficiaire (2.000 fs par Km2);

- 3°) la redevance ad valorem (3 % de la valeur carreau mine du produit).

La totalité de cette imposition paraît lourde au premier abord, mais il résulte des études faites que dans un grand nombre de cas le prélèvement fiscal effectué par l'Etat est seulement légèrement supérieur à la moitié des bénéfices effectués par les entreprises. Par ailleurs pour encourager la venue des capitaux étrangers et favoriser le développement de l'industrie un code des investissements attrayant a été adopté. Ce texte prévoit quatre régimes.

Régime A.- Les entreprises bénéficiant de ce régime sont exonérées jusqu'en 1980 de la plupart des droits et taxes perçus à l'importation. Par ailleurs elles bénéficient de l'exonération de la taxe à la consommation (5 % pendant cinq ans).

Régime B.- Les entreprises qui bénéficient de ce régime bénéficient des exonérations prévues au régime A et sont exemptées en outre de l'impôt sur les bénéfices industriels et commerciaux, et de la redevance minière pendant les cinq premières années d'exploitation.

Régime C.- Ce régime prévoit l'établissement d'une convention de longue durée (20 ans au moins) stabilisant les conditions d'exploitation, de formation professionnelle et déterminant les réalisations à caractère social. La convention donne des garanties en matières juridiques et financières et détermine en cas de litige un arbitrage international.

Régime D.- Ce régime prévoit non seulement l'établissement d'une convention de longue durée, mais aussi la stabilisation pendant 25 ans du régime fiscal accordée à l'entreprise.

FISCALITE PETROLIERE

En dehors des régimes mentionnés plus haut, un régime fiscal particulier a été adopté pour les exploitants pétroliers en raison de l'importance de ces affaires. En effet les entreprises se livrant à la recherche et l'exploitation des hydrocarbures sont exonérées de tous les impôts importants du régime commun. Elles sont soumises par contre :

- 1°) à une redevance égale à douze et demi pour cent de la valeur départ champ des hydrocarbures;

- 2°) à un impôt direct sur le bénéfice calculé de telle façon que le montant total du prélèvement fiscal effectué par l'Etat soit égal à la moitié des bénéfices.

Les exploitants pétroliers bénéficient d'autre part de la convention prévue au régime D du code fiscal.

V/- FORMATION DE GEOLOGUES, D'INGENIEURS DES MINES.

Les besoins du Cameroun en techniciens des Mines et de la Géologie restent importants. La formation de ces cadres ne pose pas de problème insoluble. Faute d'avoir sur place un établissement qualifié, la République Fédérale du Cameroun continue à faire former ses Ingénieurs et Techniciens à l'Etranger. Dans ce domaine, l'octroi des bourses aux jeunes camerounais par des organismes internationaux ou par des pays amis serait particulièrement apprécié.-

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LA MECANIQUE DES SOLS APPLIQUEE A LA CONSTRUCTION DES PETITS BARRAGES EN TERRE

Par J. DUNGLAS,
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de Génie Rural

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

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Chef de la Section de Mécanique des Sols et Génie Civil
du Centre de Recherches et d'Expérimentation de Génie Rural

1 . La petite réserve . Intérêt et caractéristiques

La petite réserve obtenue en barrant par un barrage en terre de faible dimension une vallée peu profonde, est apparue depuis quelques années, comme l'une des meilleures solutions pour l'alimentation en eau d'irrigation des périmètres isolés et même, dans beaucoup de cas, pour la fourniture en eau potable de collectivités rurales.

Cette technique, très ancienne a retrouvé une nouvelle jeunesse avec le développement de la Mécanique des Sols. Elle est maintenant très répandue dans certains pays d'Asie, aux Etats-Unis et en Europe, en particulier en Italie.

Les digues en terre ainsi édifiées, ne sont pas conçues suivant les mêmes critères que les grands barrages en terre compactée, quoique la mise en place des matériaux se fasse de la même façon. Les caractéristiques propres de ces ouvrages, sont les suivantes :

- leurs bassins versants ne dépassent jamais 500 à 1.000 ha et ils ne barrent en aucun cas, des cours d'eau importants,
- leurs hauteurs sont comprises entre 7 et 12m et ils ne dépassent que très rarement 15m,
- leurs capacités varient de 10.000 à 500.000 m³,
- leur construction doit utiliser le moins de béton possible,
- ils sont en général, édifiés en moins de 3 mois.

Depuis la recherche des sites jusqu'à la mise en oeuvre, toute cette technique est basée sur la Mécanique des Sols.

2 . La recherche des sites

Les sites possibles sont choisis, au départ, en fonction de critères topographiques, hydrologiques et géologiques. Il faut trouver une cuvette étanche, facilement obturable avec un bassin versant de faible superficie mais suffisamment alimenté. Le sol de la réserve doit être imperméable et les terrains avoisinants doivent pouvoir fournir les matériaux nécessaires à l'édification du remblai.

L'étude se fait d'abord à l'échelle de la petite région sur carte et stéréophotographies aériennes, avec les relevés pluviométriques et les débits des cours d'eau. Elle est suivie par une visite sur place d'un ingénieur spécialiste. Les critères de son choix dépendent alors directement de la Mécanique des Sols :

- obtention de la plus grande valeur possible du rapport : $\frac{\text{capacité de la retenue}}{\text{capacité du remblai}}$;
- bonnes fondations ;
- présence à moins de 500 m, d'une zone d'emprunt avec de bons matériaux ;
- étanchéité de la retenue ou possibilité de la réaliser par des moyens simples et économiques.

L'idéal est de pouvoir faire accompagner ce spécialiste, par un petit laboratoire mobile (véhicule tous terrains, très maniable) pouvant faire les analyses de définition et procéder à des essais rapides de perméabilité.

3 . Etude de l'emplacement et des matériaux

Une étude approfondie de la structure et des matériaux de la fondation et de la zone d'emprunt est toujours nécessaire.

a) La fondation

C'est une partie très importante de l'ouvrage et celle comportant le plus d'inconnues. Une fondation mauvaise entraine de très gros risques de ruine. Améliorer une mauvaise fondation nécessite toujours des aménagements coûteux. Quels sont les critères d'une bonne fondation ?

- Elle doit être capable de résister aux efforts de cisaillement dus au poids de l'ouvrage;
- Elle ne doit pas présenter des tassements trop accusés ;
- Elle doit être suffisamment imperméable pour éviter toute infiltration pouvant entrainer des sous-pressions importantes et des risques de "renards" (érosion souterraine régressive).

Des sondages sont toujours nécessaires,sauf dans le cas rarissime où l'on trouve, sous la terre végétale, le rocher franc. Ils sont menés jusqu'à une profondeur moyenne égale à la hauteur du barrage. On emploie pour ces sondages, des tarières à main et des sondeuses motorisées légères. La tarière ne donne que des échantillons remaniés sur lesquels on peut faire uniquement des essais d'identification. L'obtention d'échantillons non remaniés pouvant être soumis à des essais mécaniques, nécessite des outils spéciaux dont la mise en oeuvre est onéreuse. Mais cela est seulement nécessaire si l'on a des craintes sérieuses sur les propriétés mécaniques des couches profondes. Bien souvent on se contente d'explorer les couches de surface au moyen d'une tranchée au fond de laquelle sont prélevés les échantillons intacts non remaniés.

La perméabilité peut s'évaluer très rapidement "in situ" au moyen d'un matériel rustique (méthode du trou de la tarière). Il existe toutefois des appareils modernes pouvant donner directement sur le terrain, un grand nombre de renseignements sur la perméabilité et les propriétés mécaniques des couches profondes (pressio-perméamètres). De la valeur de la perméabilité, on déduira l'ordre de grandeur du débit de fuite à travers le fond de la cuvette.

Les principaux matériaux de fondation sont : le rocher, les sables et graviers, les argiles et vases.

i) Le rocher . Il ne pose en général pas de problème, sauf s'il est fissuré. Dans ce cas, il faut ou bien dégager jusqu'à la roche saine, ou bien traiter par injection de ciment. Mais ces opérations sont en général coûteuses.

ii) Sables et graviers . Leur résistance mécanique est bonne, mais leur perméabilité est souvent trop forte. Les méthodes employées pour les ouvrages importants telles que, rideau de palplanches, injections de ciment, paroi continue de béton, sont ici trop onéreuses.

On peut diminuer les fuites en augmentant la longueur des lignes de courant, ceci, en recouvrant le sol à l'amont de l'ouvrage avec une couche de matériaux imperméables en continuité avec les parties imperméables du barrage. Les sables peuvent également être imperméabilisés par traitement à la bentonite. Une autre solution moderne consiste à revêtir le fond de la réserve d'une couche bitumineuse ou d'un voile plastique, mais elle est coûteuse et valable uniquement pour les toutes petites retenues.

Les couches perméables en profondeur, sont également justiciables de contreforts drainants et de puits de décompression.

iii) Argiles et vases . Ce type de fondation est fréquent. L'imperméabilité est alors assurée, mais la résistance mécanique est faible et les tassements risquent d'être importants.

Il faut,de toute façon, toujours enlever les couches de surface les plus mauvaises et, quand le terrain sous jacent est saturé, le drainer pour permettre la consolidation durant la construction.

Une résistance mécanique trop faible, obligera à diminuer les pentes des parements. La présence, en quantité importante de vase molle et de tourbe, interdit toute possibilité de construction.

b) Les matériaux de la zone d'emprunt

Ils doivent offrir des propriétés physiques et mécaniques convenables et se présenter en quantités suffisantes. Les évaluations des cubages disponibles doivent toujours être assorties d'importants coefficients de sécurité. De nombreux échantillons sont à prélever aux fins d'identification et il faut vérifier l'homogénéité de la couche. Une couche bien homogène est idéale car elle permet l'extraction directe par strates horizontales. Des couches hétérogènes nécessitent par contre des reprises et mélanges. Les échantillons sont toujours prélevés remaniés puisque de toute façon les terres seront ensuite compactées.

Le matériau le plus intéressant est l'argile sableuse qui est imperméable et résistante. Les sables peuvent être utilisés, certains devenant presque imperméables après compactage. L'argile est moins résistante et la permanence de sa cohésion est sujette à caution. Elle peut être utilisée comme noyau imperméable dans les barrages à zones. Il existe des grilles granulométriques indiquant par simple lecture, si un sol convient.

c) Les essais à réaliser sur les échantillons

Les échantillons de la zone d'emprunt et de la fondation sont d'abord soumis aux essais de définitions c'est-à-dire la granulométrie et les limites d'Atterberg.

On détermine également la perméabilité et, pour les terres de remblai les caractéristiques de compactage. Il s'agit là d'essais relativement rapides, facilement réalisables dans un laboratoire mobile. Ces essais sont bien souvent suffisants pour les petits ouvrages et beaucoup d'ingénieurs en déduisent, par relations statistiques, les propriétés mécaniques.

Un tel procédé est très économique mais demande, pour être sûr, une grande expérience. Il faut éviter toute transposition hâtive et avant d'utiliser ce procédé, bien connaitre les sols de la région où l'on travaille. Si l'on a le moindre doute, on doit procéder aux essais mécaniques classiques : résistance au cisaillement et compressibilité.

Pour les toutes petites digues, inférieures à 7 m, seules les mesures d'identification sont nécessaires.

4 . La conception et le projet

Pour des raisons de prix, on préfèrera les ouvrages de type homogène, avec filtre amont et drain de pied aval, qui sont les plus faciles à mettre en oeuvre. Ils pourront parfois être du type à zones.

Le travail essentiel du projeteur est de déterminer la section transversale offrant la plus grande sécurité possible, compatible avec l'économie.

a) Pente des parements

On trouve, dans les manuels de Mécanique des Sols des tableaux donnant en fonction des caractéristiques de définition des sols et de la hauteur des ouvrages, la pente correspondante des parements. Ces tableaux sont très utiles pour dessiner directement les sections transversales des petites digues. Mais dès que l'on dépasse 7 m il vaut mieux faire une évaluation même rapide de la sécurité, par le calcul. La méthode la plus employée est celle, classique, de Fellenius. Le coefficient de sécurité S donné, représente le rapport entre les forces maintenant le parement en place et celles ayant tendance à le faire s'écrouler.

$$S = \frac{C\,L + \operatorname{tg}\phi\,\Sigma\,(N - U)}{\Sigma\,T}$$

C = cohésion , L = longueur du cercle de rupture , ϕ = angle de résistance au cisaillement , N et T = forces normales et tangentielles dans chaque tranche , Σ = signe de sommation à toutes les tranches , U = pression interstitielle.

Le calcul est toujours fait dans le cas, le plus défavorable, de la vidange rapide. Le coefficient de sécurité ne doit pas, en principe être inférieur à 1,4 , 1,5. Il existe d'ailleurs des méthodes plus élaborées que celle de Fellenius, mais les incertitudes sur les propriétés mécaniques et leur évolution, l'homogénéité des matériaux, l'évaluation de la pression interstitielle, leur enlève beaucoup d'intérêt.

En fait, pour les petits ouvrages, sauf cas exceptionnel, la sécurité est toujours largement assurée. Il est d'ailleurs toujours facile de l'augmenter en adoucissant légèrement les pentes des parements. ce qui n'est jamais très coûteux.

b) Protection et filtre amont

La protection contre l'érosion et les vagues, consiste habituellement en des enrochements en vrac ou en un perré appareillé. On emploie aussi les bétons bitumineux et des dalles de béton ordinaire non jointives. En dessous, un filtre protège les matériaux fins du remblai et empêche leur entrainement par l'eau lors d'une vidange rapide.

c) Drain de pied aval

Ce drain a pour but de rabattre la ligne d'eau interne pour empêcher les suintements et les érosions sur le parement aval. Il est calculé suivant la classique règle des filtres.

d) Infiltrations à travers le barrage

Le débit de fuite s'évalue à partir du coefficient K de Darcy et du dessin dans une section droite du réseau des lignes d'écoulement et des équipotentielles. Ce dessin peut, en général, s'établir directement dans les cas simples.

5 . Edification et Contrôle de chantier

Une édification correcte est indispensable. La terre est disposée couche par couche et compactée par des rouleaux à pieds de mouton ou à pneumatiques à gros dessins. Le contrôle de chantier, strict, doit faire respecter les cotes géométriques du projet et la mise en place des terres suivant les normes données par le laboratoire. Le sol doit être compacté au taux d'humidité optimal et à sa densité sèche maximale (optimum Proctor). On détermine sur une aire d'essai, avant la mise en route du chantier, le nombre de passages du rouleau nécessaire.

Ces contrôles sont faits par un petit laboratoire mobile. Le taux d'humidité est déterminé par dessèchement et pesée. La densité est mesurée au densitomètre à membrane ou évaluée au pénétromètre. Des appareils modernes mesurent la densité par absorption des rayons gamma et le taux d'humidité par la diffusion des neutrons rapides. Ils sont très commodes mais onéreux et nécesaitent des étalonnages fréquents ; ils peuvent également être dangereux en cas d'accident.

6 . Les crues et la submersion

Une submersion prolongée détruit à coup sûr tout barrage en terre construit suivant les techniques actuelles. Pour éviter ce danger, un bon évacuateur de crue est nécessaire. Son étude sortirait du sujet. En fait, pour diminuer les débits de crue et les apports solides, le mieux est de réduire au maximum les bassins versants.

Il existe toutefois des cas où un barrage submergé n'a pas été entièrement détruit. Tout dépend ici, du rapport entre l'énergie nécessaire pour détruire la digue et celle accumulée dans l'eau sous forme potentielle. Si la retenue se vide plus vite que le barrage ne s'érode, il se formera seulement une ou plusieurs fentes en V dans l'ouvrage. Si la réserve est vaste, tout risque alors d'être emporté. L'argile compactée est le matériau le plus résistant à l'érosion.

Une submersibilité même limitée serait du plus grand intérêt, en particulier dans les régions où l'on a peu de données hydrologiques.

Pour permettre cette submersibilité, il faudrait former à la surface de l'ouvrage une couche souple et imperméable (le bitume convient bien mais est trop cher). Des recherches vont être entreprises dans ce sens.

7 . Conclusion

La Mécanique des Sols intervient par ses concepts, ses procédés de calculs, ses essais et ses recherches à tous les stades de l'édification des petits barrages en terre. Ceux-ci doivent toujours être étudiés et réaliser avec grand soin malgré leur faible importance. Il y a peu de progrès à attendre du raffinement des calculs et des essais. Il faut plutôt chercher à diminuer les coûts d'étude et de réalisation par l'emploi de méthodes nouvelles.

La sécurité ne doit en aucun cas être compromise. La notion de risque doit ici servir de guide. Des petits ouvrages dont la rupture n'aurait que des conséquences matérielles limitées peuvent être édifiés après des études sommaires. Leur rentabilité peut d'ailleurs se chiffrer d'après leur probabilité de destruction à plus ou moins brève échéance.

Pour des barrages plus importants dont la rupture entrainerait des pertes en vies humaines, il faut être beaucoup plus prudent et utiliser toutes les ressources de la Mécanique des Sols dans la conception et la réalisation.

La structure des petits barrages en terre évoluera sans doute dans l'avenir. Des composés chimiques capables d'améliorer les propriétés physiques et mécaniques des sols vont apparaître à des prix intéressants. Les petits ouvrages, du fait de leurs cubages peu importants pourront rapidement en bénéficier. Le remblai compacté deviendra de plus en plus un produit manufacturé.

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India

APPRAISAL OF EXISTING RESOURCES, USES AND REQUIREMENTS AND ALLOCATION TO DIFFERENT USES WITH PARTICULAR REFERENCE TO INDIA

By BALWANT SINGH NAG

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APPRAISAL OF EXISTING RESOURCES, USES AND REQUIREMENTS AND ALLOCATION TO DIFFERENT USES WITH PARTICULAR REFERENCE TO INDIA

by

Balwant Singh Nag

Ignoring the small utilisation of converted fresh water from sea water for municipal and industrial uses, precipitation in the form of rainfall or snowfall constitutes the primary source of water in any country. The eternal cycle of evaporation, cloud formation and precipitation plays the vital role of annual replenishment of water resources that get used or lost and thus nature maintains the balance. Where rainfall is plentiful, water resources are ample though they may not necessarily lend themselves to economic or full exploitation. In making an appraisal of water resources, it is more important to know the portion which can be put to beneficial use rather than the total quantity.

RAINFALL AND SNOWFALL

2. The sub-continent of India, which lies partly in tropical and partly in sub-tropical region and where land heights vary from sea level to very high mountains, has a wide range of rainfall varying from about 5 inches (130 mm) in the desert on the north-west to over 400 inches (10,160 mm) in the Cachar hills of Assam. The average rainfall of India is 41 inches (1041 mm) .Most of the rainfall is concentrated in the monsoon months of June to September when the south-west monsoon brings general, though not continuous, rainfall through out the country. The total rainfall of this period is about 100 inches (2,540 mm) over part of the west coast; the amount diminishes eastward to below 30 inches (760 mm) over a large part of the central and eastern Peninsula; it is over 100 inches (2,500 mm) in the north Assam valley and diminishes steadily westward, to only about 5 inches (130 mm) in the western part of Rajasthan. The contribution of north-east monsoon which lasts from October to December, is comparatively small and is confined primarily to peninsular India. There is practically no rainfall in the country for the rest of the year. There is not only marked variation in rainfall from one part of the country to another but also from year to year. It is not uncommon in many places for rainfall in a year to be less than half the normal, and in some cases, even much less during critical periods in crop growth when water is needed most.

3. The contribution from snowfall is confined to the Himalayan mountains which stretch over a length of 1500 miles (2415 km) along the northern boundary of the country. There are about 50 peaks with heights exceeding 24,000 feet (7315 metres) and these high altitudes are the abodes of numerous glaciers which give rise to perennial rivers flowing through the vast plains of

northern India. December to February is the snow accumulation season in these mountains. Precipitation occurs at intervals throughout this period, generally in the form of snow at higher levels, snow and rain in the lower hills and some rain over the adjoining plains. As this precipitation is caused by a series of weather disturbances which cross into northern India from the west and travel eastwards along the Himalayas, the precipitation decreases from west to east upto Sikkim, from where it increases to a certain extent, probably because of some additional moisture which becomes available on account of nearness of the sea. Temperature in these mountains starts rising in March. From this month to May or June is the snow-melt season when a very large proportion of the winter snow-cover melts away and contributes to the flows of the snow-fed rivers. While the melting of snow continues during the monsoon season, June to September, its contribution forms an insignificant fraction of the flood flows brought about by abundant rainfall during this period. For the remaining months October to November, the discharge of these rivers is made up almost entirely of ground water. It has been broadly computed that the percentage contribution from snow to the river runoff during the snow-melt season ranges between 20 to 90 per cent in the western rivers like the Jhelum and the Sutlej, to less than 5 per cent in the eastern rivers like the Gandak and the Teesta. Viewed for the year as a whole, the contribution from snow-melt is, therefore, not large, although it augments the river supplies in the dry months of March to June and provides the much-needed water for irrigation.

EVAPORATION AND OTHER LOSSES

4. Of the quantity of water which is annually contributed by rainfall, a good deal is lost through evaporation and transpiration. Also, there are losses into the subsoil, but what goes into the ground at any time reappears to a large extent as regeneration water ultimately. Unless, therefore, leakages occur from one catchment to another, the ground water loss can be ignored in determining the average water yield of a catchment area. Temperature plays a dominant role in the rate of evaporation and transpiration in a catchment area. Sunshine, clouds, wind velocity and humidity are also relevant but these generally follow the temperature cycle, and by and large can be taken to be represented by it. The mean annual loss, measured in terms of depth in inches, varies in different river basins of India from about 29 inches (740 mm) for rivers falling into the Bay of Bengal other than the Ganga and the Brahmaputra, to about 13 inches (330 mm) for Indus Basin lying in India. In Rajputana, the entire annual rainfall which is a meagre 11.5 inches (290 mm) is lost through evaporation and transpiration.

5. Evaporation from snow, because of low temperatures in the snow regions, is relatively small, being of the order of 0.1 inch (2.54 mm) per month at 0° F (-18°C) and 1.5 inches (41 mm) per month at 32° F (0° C). Above this temperature, the rate of evaporation progressively increases, but is a small percentage of the rate of snow-melt. For instance, while snow-melt at 72° F (22°C) is of the order of 60 inches (1524 mm) per month, evaporation is only about 7 inches (178 mm).

SURFACE WATER RESOURCES OF INDIA

6. Nature has blessed India with vast and bountiful water resources, both surface and ground water. The annual precipitation over the entire country represents something more than 3,000 million acre feet (37,000 mhcm) of water. As has been mentioned earlier, a good deal of it is lost through evaporation and transpiration. A part of it soaks into the ground to re-appear as regeneration flow. The first attempt at appraisal of the overall river water resources of India was made in 1949. In the absence of actual observed data for most rivers, this appraisal was based on an empirical formula which Dr. A.N. Khosla had evolved on the basis of his concept that annual or seasonal runoff is the residual of rainfall after deduction of evaporation and transpiration losses, and that the mean temperature is a complete measure of all the various factors affecting the evaporation and transpiration losses. The shape of the catchment, the slope and vegetal cover would have an effect on the seasonal distribution of runoff, but not on the aggregate runoff. The formula is:

$$R = P - \frac{T-32}{9.5}$$

where R = runoff (inches)
P = rainfall (inches)
T = mean temperature (degrees Fahrenheit)

Generally, T is taken as the mean monthly temperature. If the loss $L = \frac{Tm-32}{9.5}$ is calculated for monthly mean temperatures, the monthly losses can be aggregated to give the seasonal or the annual losses, and with corresponding figures used for the rainfall P, the corresponding monthly, seasonal or annual runoff can be determined. On the basis of the above formula, the result of the computations that were made was as under:-

(a)	Total catchment area of all the rivers	1,430,937 sq. miles (370,46,96 km^2)
(b)	(i) Normal annual rainfall	41.03" (1042 mm)
	(ii) Equivalent quantity of water.	3130 maft (38609 mhcm)
(c)	(i) Evaporation losses	23.26" (591 mm)
	(ii) Equivalent quantity of water	1774 maft (21882 mhcm)
(d)	(i) Annual runoff	17.77" (451 mm)
	(ii) Equivalent quantity of water	1,356 maft (16726 mhcm)

For the purpose of making estimates of the water resources of the various river basins, the country was divided into six major regions. These regions, the aggregate catchment areas of the riversin each and their computed runoff are stated below:-

Rivers	Total catchment area(sq.miles)	Runoff (maft)
(a) Rivers falling into Arabian sea (excluding the Indus system)	189,790	252
(b) Indus basin (in India)	136,673	64
(c) Rivers falling into Bay of Bengal, other than Ganga and Brahmaputra systems	460,309	334
(d) Ganga system	376,818	397
(e) Brahmaputra system	195,460	309
(f) Rajputana	64,887	-
Total:	1,430,937 ($37,046,96$ km^2)	1356 (16726 mhcm)

DEPENDABLE ASSESSMENT OF SURFACE WATER RESOURCES

7. Empirical formulae for the assessment of water resources have their value where actual reliable data over a period are not available, but these are no substitute for actual observations. In making an assessment of water resources, it is not sufficient only to determine the supplies of water in the river, but also the extent to which these supplies are available at the right time and place and whether they are susceptible of being conveyed and distributed over any desired area by economic projects. No large water resource development project can be based with a degree of reliability and confidence in the absence of adequate and satisfactory record of rainfall, runoff and flood data. The availability of water at any location alters with changes in utilisation and other conditions upstream. It is, therefore, essential to have continuous and long-range measurements of available water in order to assess its daily, weekly, monthly or annual mean values with the desired degree of accuracy and reliability. A system of well-equipped hydrological stations is a pre-requisite to planning water resources development projects.

8. The essential data that are required for making an estimate of the water resources of a river basin are :-

(a) Topographical maps of the entire river basin.
(b) Gauge, discharge and silt data.
(c) Locations of rain gauge stations and record of precipitation.
(d) Temperature and humidity records.
(e) Geological reports.
(f) Snow survey data if there is snowfall in the catchment.

Toppgraphical maps generally furnish a large part of the necessary reconnaissance data and aid in determining the extent of field work and investigations which are required to be carried out. Aerial photographs, where available, are helpful in providing information about cultivated area, vegetal cover, geological formations, etc. Gauge and discharge data are required to assess the quantum of water available at a particular site and the best manner of controlling, regulating and utilising it. The gauge discharge studies should also cover the flood history of the river for determining peak discharges, hydrographs and frequency of occurrences. A correct knowledge of the probable rate of silting in a river basin is a matter of vital concern for any undertaking dependent on stored supplies. The silt yield of a catchment depends upon the quantity, intensity and pattern of rainfall, the slopes of the terrain, the nature and extent of vegetal cover and the type of soil. Rain gauge stations should be situated in representative locations and there should be an adequate number of these in a catchment area, as otherwise, misleading results can arise. Apart from the knowledge of the total rainfall at a given station, it is important to know the rainfall intensities for various durations.

9. The accuracy of the assessment of water resources in a river basin will depend on the consistency reliability and adequacy of the data which may be available. The gauge and the discharge data should be scrutinised in respect of the methods of observation and the nature of the measuring equipment used and the method of computations adopted. Before using rainfall records for computing runoff flows, it is necessary to scrutinise whether the period of record has been continuous, the locations of the rain gauge stations have not been altered during the period and other indeterminate instrumental and observational errors have not crept in.

10. An important aspect to be considered is the loss of water due to seepage and transmission and the gain through direct return flow of part of the used water and on account of regeneration. Return flow from irrigation may amount to as much as 30 to 60 per cent of the irrigation water supply. The re-generated water can be used again on projects located downstream. Again, in the case of domestic water supply, a portion returns to the ground or to the stream as sewage with or without treatment. Re-use of such water for certain purposes depends on the degree of pollution and the treatment accorded to it. Similar is the case with water used in industry. Here the major requirement is for cooling purposes and a large portion of cooling water returns to the river or is available for re-use. It is, therefore, necessary to make an estimate of water actually consumed and the portion that may return to the ground or the stream in useable quality when making an assessment of the water resources of a basin.

11. The study of water resources of a river basin involves the following steps:-

(a) An assessment of the existing quantum of water consumptive utilisation on various projects and schemes.

(b) An assessment of the additional surface water requirements for consumptive uses for full development of existing projects.

(c) An assessment of absorption and transit losses and return flow from regeneration both under existing conditions and with additional appropriation for full development of existing projects.

(d) An assessment of evaporation losses from reservoirs, canals and river basins.

For forecasting the residual water resources in a river basin after the existing planned projects have reached full development, it is necessary to predict, if possible, the trend of future changes in losses and gains with a view to determining the cumulative effects under the changed hydraulic conditions of the river. Drastic changes in the hydrologic conditions of the river system will cause consequential changes in the quantum of loss and gain, and these would be important in appraising the river supplies for future needs.

UTILISATION OF SURFACE WATER RESOURCES

12. The surface water resources in a country can be put to a variety of uses such as irrigation, domestic and industrial water supply, hydro-electric power generation, navigation, river conservancy, reclamation of saline lands and salinity control in coastal areas. In considering the utilisation of river waters, distinction has to be made between consumptive and non-consumptive uses. Irrigation is regarded completely as a consumptive use although part of the water applied to irrigated lands may re-appear through seepage as regenerated water. Water used for municipal purposes as also in industries is partly returned back to the stream or is other-wise usable for other purposes, after proper treatment. Hydro-electric generation does not involve any appreciable consumptive use of water, although where storage is created for power generation, the evaporation loss from the reservoir reckons against consumptive use.

13. India has predominantly an agricultural economy, and as such irrigation assumes great importance in its development. Irrigation has been practised in the country since times immemorial. The nature of irrigation works adopted for utilising surface waters was determined by the pattern of flow in the river systems tapped. For instance, in north India with numerous snow-fed perennial rivers, the earlier irrigation projects were mostly river diversion works. For irrigating larger areas, where run-of-the-river flows during the

non-monsoon period have been found inadequate, it has in recent times been necessary to build storage works. In the southern part of the country where river flows dwindle in summer months, the practice of storing water in irrigation tanks during the monsoon period came into vogue. There are about 100,000 such tanks in this part of the country, some of which date back to many centuries. From their very nature, these tanks irrigated a relatively small block of area each. The replenishment of water in these tanks depends on the rainfall which, in zones of low rainfall is mostly erratic. These tanks, therefore, often fail to fill up in periods of drought when water is needed most. Some of the larger storage projects taken up in recent years, however, promise a more dependable source of irrigation as, with their larger catchments, the effect of local vagaries of rainfall is greatly evened off.

14. Hydro-electric power is generally a very cheap source of energy as no fuel consumption is involved. In 1953, the Central Water and Power Commission undertook the task of systematically assessing the total hydro-power potential of India, based primarily on a study of topographical maps and of available data on rainfall, run-off and river gauging. Allowance was made for other uses of waters of these rivers. A total hydro-electric potential of about 41 million kW has been assessed as technically and economically feasible. When field investigations are made, this figure is likely to be exceeded. Of this considerable hydro-power potential available in the country, only about 1.9 million kW had been developed by 1961. By the beginning of 1966, however, this development is likely to be increased to 5.1 million kW.

15. No large scale use is at present being made of river waters for reclaiming saline lands. In the coastal reaches, however, large flood flows during the monsoon period help in keeping in check the upland movement of salinity. In certain States such as West Bengal and Kerala, there are serious problems of salinity and projects have been planned with salinity control as an important object.

16. As has been stated earlier, the available river water resources of India have been computed at about 1356 million acre feet(16726 mhcm). But not all this water can be put to beneficial use. On certain rivers, while plenty of water is available, conditions are not conductive for its use. The Brahmaputra river system with its annual run-off exceeding 300 million acre feet (3701 mhcm) is an outstanding example. Because of high rainfall in the Brahmaputra Valley and its narrow average width of about 55 miles, there is neither sufficient land nor any appreciable demand for irrigation in the area. Elsewhere and notably in the Peninsula, there is not enough water in certain rivers to meet the requirements. It has broadly been estimated that, out of the computed surface water resources of 1356 million acre feet (16726 mhcm), only about 450 million acre feet (5550 mhcm) are utilisable for irrigation. By the beginning of 1961, only about 120 million acre feet (1480 mhcm) were being utilised. By 1966, an additional 40 million acre feet (493 mhcm) are likely to be used for this purpose.

GROUND WATER RESOURCES

17. Although the ground water resources of India are not as large as its surface water resources, from many considerations they are no less important. In areas where there is paucity of surface water, ground water resources, assume special significance. No dependable assessment has yet been made of these resources. Certain parts of the country, such as the Indo-Gangetic basin with its water-bearing stratum extending to a depth of several thousand feet, are known to be rich in this resource. Over the past eight years, a nation-wide survey of underground resources by means of extensive deep exploratory drilling has been undertaken. The results have been encouraging. The most significant discovery has been in the water-starved district of Jaisalmer in Rajasthan with an annual rainfall of less than 10 inches (254 mm), where a borehole has yielded a flow of 51,000 gallons per minute (232 kl per min), bringing new hope in an area where there has been scarcity of water even for drinking purposes. Very promising discoveries have been made in several other parts of the country. These exploratory operations for assessing ground water potentialities are continuing in various regions covering an aggregate area of about 136,000 sq. miles (352,240 km^2). For selecting individual sites for exploration, a reconnaissance survey is normally carried out guided mainly by geological conditions and also by the results of the geo-physical traverses carried out in the area.

18. Generally, an appraisal of ground water resources should cover a study of ground water table, location and extent of underground storage, yield, movement or distribution within the water-bearing formations and determination of the changes that take place in the natural course of events or as a result of interference. The replenishment of underground water in a basin is primarily due to the contribution from surface water and, in rare cases, from leakage of underground water from a neighbouring basin. If, either due to excessive irrigation or intensified absorption of flood waters on account of obstructed waterway and poor drainage, more water is added to the sub-soil than is withdrawn for various uses, it results in the progressive rising of the ground water table. This, in course of time, can cause water logged conditions leading to large-scale deterioration of land, thereby throwing large areas out of cultivation or adversely affecting the cropping pattern. Such is the case in the Punjab where on account of rapid rise in the ground water table over the past few decades, vast areas have been badly affected and expensive and extensive remedial measures have been necessitated. On the other hand, where more water is withdrawn than is annually replenished, the ground water table gets lowered. Such is the position in Madras, where large-scale pumping of underground water for irrigation has considerably lowered the ground water table with the result that the cost of lift irrigation has been steadily increasing. If this trend were allowed to continue unchecked, the water table may get depressed to an extent that it would render lift irrigation prohibitively expensive and create difficulties even for domestic supplies. All this points to the great importance of systematic and continuous observation of

ground water table in all parts of the country where large-scale exploitation of surface or ground water is being made or is contemplated to be made. In areas where the ground water table has been noticed to be rising, restriction of canal irrigation and resort to lift irrigation might be necessary. Also, it will be necessary to open up drainages and remove obstruction to flood flows. In the case of falling ground water table, it might be necessary to restrict lift irrigation and, where feasible, augment the natural process of replenishment by artificial means. This can be accomplished by diverting surplus water from natural streams and spreading it over adjacent permeable soils; by releasing water from storage reservoirs to natural channels during periods when the channels would otherwise be dry; or by injecting water into wells, shafts or pits.

19. It is of great importance to standardise the method of observation and recording of the ground water data. The subsoil water level rises during the monsoon and, thereafter, continues to fall till the beginning of the next monsoon when it starts rising again. This fluctuation in subsoil water level varies from year to year, depending primarily on the infiltration from rainfall in that particular year, the water drawn out during the corresponding period and additions from seepage. For observing the trend of variations in the ground water level, a watch has to be maintained over a period of years. As such, observations of spring level in the observation wells, would need to be made at least once before the monsoons, say, in April and once after the monsoons in October, each year. However, in areas where there is an acute problem of rising or falling ground water table, as in the Punjab and Madras, observations at closer intervals are indicated. With the data thus collected, subsoil water contour maps should be prepared. A comparison of such contour maps from year to year would reveal where ground water table is rising or falling and the rate at which the change is taking place. With this knowledge, timely remedial measures can be taken where called for and the pattern of water utilisation modified to serve the interests in the best manner. For the observations to be most useful, it is important to select the line of observation wells with care and having made the selection not to change it. Also, the reference point for observation at each observation well should be permanently and firmly fixed and its value recorded with reference to a known near-by survey bench mark.

PRESENT UTILISATION OF GROUND WATER RESOURCES

20. The underground water resources are exploited through tubewells, filter points and open wells. There are about 20,000 private tubewells and filter points and about 5 million open wells in the country, which between them draw about 31 million acre feet (382 m h c m) per annum. In addition, there are about 9000 Government-owned deep tubewells which draw about 4 million acre feet (49 m h cm) per annum. The present annual exploitation of underground water resources in the country is thus roughly estimated at 35 million acre feet (432 m h cm).

ALLOCATION TO VARIOUS USES

21. Competing demands arise where available water is insufficient to satisfy the various requirements. In multiple purpose river valley projects, conflicts arise from multiple uses of water. These conflicts relate to storage space, time of use and discharges. Conflicts for storage space occur if a reservoir of limited capacity is expected to serve divergent purposes like flood control and water conservation. Flood control and water conservation have opposing requirements on the storage capacity. Whereas the needs of flood control demand that adequate reservoir capacity should be kept empty to absorb floods, the interest of water conservancy requires the maximum filling up of the reservoir. Conflicts in time arise in the joint use of storage water where the seasonal use pattern varies from one purpose to another. For example, such a conflict arises in the case of a reservoir which caters for both power load related to the annual peaks. Water requirements for irrigation vary with the season. Irrigation demand also varies with local precipitation. Thus, if water releases are controlled by power, it may mean that a good deal of supply will be wasted when there is no demand for irrigation water, unless other means can be found to conserve it. On the other hand, if water is conserved during periods of low demand for irrigation, power generation will get restricted during that period. In all these cases, either certain sacrifices must be made by various interests or additional costs must be incurred to bring different uses together in a unified and integrated operation of the storage. Conflicts in daily discharge also arise where power and irrigation are derived from a single reservoir. Regulating pools can, however, be used to equalize the flow from the tail race for providing a steady discharge for irrigation.

CO-ORDINATED PLANNING FOR SURFACE AND UNDER-GROUND RESOURCES

22. For rational planning of the use of water resources in an area, both the surface and the under-ground water resources should be viewed together. The exploitation of surface water resources is generally more economical than the underground water resources. But, in certain situations, where surface water has to be conveyed over long distances before it can be used, and underground water resource is available in adequate quantities and at reasonable depth, it would be cheaper and more satisfactory to use the latter. Apart from the initial capital outlay, use of underground water involves recurring cost on pumping and generally higher maintenance and operation charges. Where demands for cheaper surface water for various uses exceed the availability and sufficient underground water is available to fill the gap, it is necessary to specify the uses to which either sources should be put, as otherwise the cheaper source might get utilised for a purpose which can bear a higher cost, leaving the more expensive source for other purposes to which it may prove burdensome.

23. In India, with its predominantly agricultural economy, the major use of water resources has been for irrigation. But rapid strides are now being made in industrial development also. Problems of water supply for industrial uses

have already arisen in several areas notably in the Bihar-West Bengal region. Unless adequate supply of water for industrial and domestic uses is ensured in industrial belts, the development of industries in these areas is likely to get stiffled. It is important that, in such areas, assessment should be made of the total water resources both surface and underground, and a priority of use established, after taking a long-range view of the various requirements such as irrigation, river conservancy, navigation, power generation, industrial and domestic requirements, etc. Needless to say, that municipal requirements would ordinarily have the highest priority amongst the various uses.

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South Africa

MECHANICAL EQUIPMENT USED IN THE MINES OPERATED BY TRANSVAAL GOLD MINING ESTATES, LIMITED, PILGRIMS REST DISTRICT, EASTERN TRANSVAAL, REPUBLIC OF SOUTH AFRICA

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NOTES

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MECHANICAL EQUIPMENT USED IN THE MINES OPERATED BY TRANSVAAL GOLD MINING ESTATES, LIMITED, PILGRIMS REST DISTRICT, EASTERN TRANSVAAL, REPUBLIC OF SOUTH AFRICA.

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1. INTRODUCTION

1(a) In order to appreciate the types of mechanical equipment used in the small mines operated by the Transvaal Gold Mining Estates, Limited, it is necessary to give a background of information on the occurrence and geology of the ore-bodies in the area and a general description of the mine layouts planned for the use of mechanical equipment.

1(b) The mines operated by the company are scattered over an area of some 200 square miles in the Drakensberg Mountains of the Eastern Transvaal. The country is heavily dissected with mountain ranges reaching heights of 7,500 feet. Deep valleys and ravines reaching a depth of over 2,500 feet are caused by river erosion, thus exposing the interbedded gold carrying reefs. The mountain ranges run roughly north to south, with the formation dipping gently to the west at 4-6°.

1(c) The mines have been worked continuously since 1872. Although rich in places, they are, generally speaking, medium to low grade and with low percentage payability, with many mining difficulties caused by faulting, oxidised ground and waterlogged conditions. The presence of copper associated with the gold and, in places, arsenic causes metallurgical difficulties.

1(d) Due to these difficulties and the scattered nature of the ore bodies, the mines for the most part have been fairly low profit earners, and the last 20 years of the company's life have been a continuous struggle for survival. These conditions have dictated the mining policy. With limited ore reserves and marginal profits, capital expenditure has had to be limited. A high degree of mechanisation has not always been advisable, due to the generally very narrow reefs. In all, some thirty individual mines have been operated, with the ore milled in six separate plants strategically positioned over the 40 miles of strike of the property. There is a wide range in the size of the mines.

2. GEOLOGY OF THE AREA

2(a) The Pilgrim's Rest Goldfields occur in the Transvaal System which is probably early Proterozoic and forms the middle portion of a group of formations that are of later Precambrian age. These formations overlie the Basement Granites of archaean age.

2(b) The interbedded reefs occur mainly in the Dolomite Series which reaches a width of over 3,000 feet. The reefs dip gently to the west conformably with the strata. Some ten different super-imposed reefs have been worked in the Series. The main horizons on which the majority of the mining has been done are the Lower Theta, Beta, Portuguese and Glynn's Reefs. The reefs for the most part are narrow in width with erratic payability. Similar reefs are found above and below the dolomite in the Pretoria and Black Reef Series. Leaders have been found dipping across the strata. Due to the extensive river erosion which generally runs parallel to the strike of the country, the rock formations new surface are heavily weathered and decomposed, with the reef outcrops oxidised. At varying distances from the outcrop the dolomite becomes extremely hard and cherty and the reefs pyritic. Slumping and solution faulting are common.

FIGURE I shows a typical columnar section through the rock formations near Pilgrim's Rest.

3. GENERAL DESCRIPTION OF THE MINES

3(a) The erratic nature of the gold distribution and the average low percentage payability, which is less than 5% for the area in general, make long term planning of mine layouts difficult. In most cases mines are opened up from payable outcrops by adits into the hillsides or by inclines sunk on the dip of the reef. Workings follow the payability, and prospecting is done by underground development. Diamond drilling from surface for prospecting the dolomitic reefs has not proved reliable due to the hardness and broken nature of the dolomite, and the soft oxidised or friable pyritic reefs. Payability has extended long distances underground from the original outcrop, for example, at Glynn's Lydenburg mine workings extend over 20,000 feet into the mountains.

3(b) The reefs in general dip away from the outcrop giving rise to underground water problems. The dolomite in some areas carries large quantities of water, and amounts in excess of 6 million gallons per day have been encountered in headings underground. Low level drainage drives are developed when possible for dewatering the mines. In one instance a drive of nearly 15,000 feet tapped 13 million gallons per day.

3(c) In the mountainous areas a number of super-imposed payable reef bodies occur in places. The scattered payability and terrain are the main consideration in determining the method of surface ore transport to the mills. Wide use has been made of various types of rope haulages.

3(d) Many systems of stoping have been used with varying degrees of mechanisation. Limiting factors are the irregularities and the narrow reef widths. The values are usually such that a clean uncontaminated product must be sent to the mill.

4. STOPING

4(a) For interbedded consistent hard rock reefs dipping between 0^{o} and 20^{o} with reef widths over 20 inches, cleaning by scraping has proved most efficient. For reasonable working conditions stope widths should not be less than 28 inches, while widths in

excess of this can be handled satisfactorily with scrapers. The stope width is determined by the reef width and the position of suitable parting planes in the rock strata. The length of the scraper pull is determined by payability and the production rate required.

4(b) A typical stope on sulphide reef is as follows:- The length of scraper pull on face is 300 feet. The stoping width is 30 inches with a reef width of 20 inches. 100 face holes are drilled per shift by 2 machine crews of 2 men each. The depth of hole is 42 inches. The face is blasted once per 24 hours with cleaning on the opposite shift. 200 square fathoms are broken per month with a production of 60 tons per shift handled to surface. The face advance is 24 feet per month. The method of support is 4 feet square 4-pointer waste filled timber cribs, with reef scatterpile for protection from blast scatter. 15 h.P. scraper hoists with a rope speed of 200 feet per minute pull a scraper shovel with a capacity of 0.4 tons. The length of the scraper pull can be shortened for increased production with closer hole spacing.

4(c) With narrower reefs it has been found that some type of resue stoping method is advantageous. Straight stoping of narrow reefs causes excessive dilution of broken ore values, and higher tonnages for transport over the long distances to the mill. With this method of stoping, scrapers have been found to be ineffective as excessive quantities of waste are removed, and control of grade is difficult. An effective stoping system is the herringbone, with strike tracks varying from 24 to 40 feet apart on dip. Track height is obtained by footwall lifting, and the tracks are kept close to the face. Care is required with track direction to avoid convergence, as strike determination on flat dips is difficult. Survey direction lines are usually carried. Stope cars of .5 ton capacity are handloaded at the face, and handtrammed to the centre incline rope haulage or scraper gulley. In the latter case end tipping cars are used on the strike tracks fitted with gooseneck rails at the tipping point. The distance of strike tram is determined by hanging-wall conditions,and is inefficient at distances in excess of 300 feet. In resue stoping waste over or under cuts are made and this product packed in the stope. Reef is lifted when convenient, and production from a pair of faces can be fairly evenly maintained. Should reef be broken inadvertently during the waste cut, it is hand-sorted and removed before the next blast. Reef ledges of 10-12 feet are cut before being lifted.

4(d) With a semi-oxidised ore in hard dolomite country rock as at Vaalhoek mine, a short cycle over cut resue system was most effective. Each daily waste blast is removed to the waste fill by handlashing. Following this operation, the reef is mined as far as possible by a crew using pneumatic picks. On completion of the waste removal, the scraper commences reef removal starting from the top. The sweeping crew then follows the scraper down until all reef is removed and the stope completely swept. At this stage the face is ready for the machine crew to drill the holes for the waste cut. The cycle is completed in eight hours for a face length of 250 feet. With a reef width of 9 inches, a mill width of 15 inches is expected. Stopes valued at 120 inch-dwt. produce a product to the mill of approximately 7 dwt. Monthly face advances of 12-15 feet were

obtained with a daily production of 18 tons of reef per face.

4(e) Under soft ground conditions, mechanical cleaning by scrapers is usually unsatisfactory, due to the usually limited face length that can be kept open and the soft nature of the country rock. When stope timbering is required on the face, handlashing to stope tracks 24 feet apart on dip is a most effective method. It is not uncommon for top spiling to be required on the face from timber stringer sets erected at 4-5 feet centres on dip. The waste overcut is packed back, the reef is lifted by pneumatic picks, and removed either by hand shovel to stope trucks or when the grade of ore is high into jute pockets for transport to surface. With wider reefs and stronger ground conditions, shaker shutes suspended from the timber sets have been used. These can be hand or pneumatically operated and are used for dips between 0^{o} and 10^{o}. Good supervision is required for effective operation of this type of equipment.

4(f) A resue method of stoping was used in the vertical reef in Rietfontein mine where the reef occurs in the basement granites with one sidewall decomposed for a distance of 2-4 feet. A reef drive connection is made on a payable stretch and is fully timber set. Overhand stoping then commences and the reef removed down double cribways 50 feet apart on strike. The soft sidewall is stoped by picking 4-6 feet up alongside the reef. This waste product is packed on the sets between the cribways. On completion of the waste cut cycle, the reef is blasted down on to flat slab lagging lain on the waste fill. The reef is blasted to within 2 feet of the advanced waste cut. The reef is removed by handlashing into wheelbarrows or by small portable 7½ H.P. air operated scraper units. A vertical back between levels of 150 feet is convenient. Cribways are double, one side for reef removal and the other side for services, travelling and for clearing hung up rock. Two-inch pipes are effective speaking tubes for communication between the level below and the working face. A full shrinkage stoping method is unsatisfactory as the soft sidewalls collapse at the withdrawal stage. Underhand stoping with loaded stulls is unsafe due to sidewall caving.

4(g) Normal 2⅛" hand held jackhammers are used with ⅞" hexagonal 46 inch tungsten carbide tipped drill steel, with a tip gauge of 44 m.m. There was an improvement of over 30% in drilling performance in hard dolomite with chert bands with the introduction of tungsten carbide steel, compared with detachable forged bits or forged steel. An average of 560 feet drilled per rod is obtained at a cost of 84 cents per 100 feet. Rubber collars have proved more effective than forged shanks and are cheaper. Air legs have replaced stopers in steep overhand workings. Pneumatic hand held pick machines weighing 15/20 lbs. are most effective in oxidised ground. These machines require little maintenance and their extensive use has resulted in a marked improvement in productivity.

4(h) With wide orebodies outcropping or occurring near surface the opencast method of mining can be highly productive and economical. Where the orebodies are massive the operation is mechanised to a high degree but where the ore occurs in a stockwork of leaders which require clear mining for grade control, limited mechanised equipment can only be used and hand loading is satisfactory. An

important consideration is the ratio of waste removed to ore produced, the actual ratio depends on the value of the ore.

4(h)(i) A detailed knowledge is required of the orebody before planning a waste stripping operation and siting the waste dumps. A diesel operated shovel loader and an electrically operated scraper have been used. The former has a high purchase cost and requires a number of self tipping trucks, depending on the length of tram to the dump site. This equipment is highly flexible and mining can be selective. A ½ cu.yard shovel handles 400-500 tons per shift at a cost of 50-75 cents per ton depending on the type of ground. A 60 H.P. scraper unit removes 150 tons per shift. This method although cheap in initial outlay can only operate in fairly soft ground and selective mining is difficult.

5. UNDERGROUND HAULAGE SYSTEMS

5(a) With mines operating near surface the broken ore tends to be sticky and is difficult to handle in gravity systems such as ore-passes. Various types of rope haulage systems for handling trucks loaded at the face have been found effective over long distances underground. They have a low cost of installation and maintenance. Diesel operated locomotives have proved most satisfactory underground when track gradients are suitable. They are cheaper both in installation and operating cost than electric battery locomotives.

5(b) Reversible Rope Haulages.

5(b)(i) Two types of reversible rope haulage systems have been used. The main and tail, using a winch at both ends, and the endless rope with a single reversible driving unit. Both employ a single track. The latter case has several advantages over the former. It is cheaper since it has only one driving unit. It can pick up or drop off trucks fitted with rope clamps, such as gooseneck jockeys, without stopping the system. The signalling requirements are far simpler since only one driver is required.

5(b)(ii) A 6,000 ft. reversible endless rope haulage easily deals with the output from 6 inclines feeding to it. Trucks fitted with jockey brackets are fed onto the rope and knocked off at the inclines as required. The process is reversed to haul back the fulls. The haulage system can be adapted to feed to a shaft at one or both ends of the haulage. The rope speed is 4 miles per hour. The diameter of the rope ¾ ins. and the 4 ft. diameter fleeting wheel is driven by a 60 H.P. motor. Tonnage handled is 240 tons per 8 hour shift. This type of haulage is suitable for an elongated ore body. A series of this type of haulage served a mine with a strike length of some 11,000 feet with the length of the orebody on dip averaging only 150 feet. The pitch of the orebody was 4^{o} against the load.

5(c) Endless Rope Haulage.

5(c)(i) This type of haulage is best for flatly dipping reefs where payability extends approximately equal distances on dip and strike. The haulage has no difficulty negotiating bends where a system of rollers guide the rope on the jockey brackets round the curves. A number of horned rollers are used on each bend to keep the rope in position on the remaining rollers. The track plan of the haulage

can be square, rectangular or in a figure eight.

5(d) Endless Rope Double Track

5(d)(i) This system has a high capacity and is installed where conditions permit of a double track. It is best suited for feeding from point to point such as from a collecting level to surface via a main adit. A haulage of this type has a capacity of 460 tons per 8 hour shift over a distance of 2,500 feet. Flat bottomed 12 cu.ft. cars are used with 30 lb. track at 18" gauge. The rope diameter is ¾" with a speed of 4 m.p.h.

5(e) Single Track Hoisting

5(e)(i) The commonest system used is the single track, single drum electric winch hauling from stopes on the herringbone system or a direct haul from one level to another.

5(e)(ii) A typical unit consists of a 30 H.P. electric motor geared to a drum giving a rope speed of 4 m.p.h. hauling up an incline of 7° to 10°. The length of haul is 500 feet with a rope diameter of ½ ins. and a rock load of 3 tons. An average performance of such a unit in a herringbone stope with turnouts at 40 ft. intervals is 42 tons per 8 hour shift. On a straight haul from one level to another the output is 160 tons per 8 hour shift.

5(f) FIGURE II gives the layout of a flat dipping mine using various types of haulages feeding to two vertical shafts. The mine produced 5,500 tons of reef per month and 4-5,000 tons of waste.

6. SURFACE HAULAGE SYSTEMS

6(a) The topography of the country, the distances involved, the tonnage to be handled and the capital available, are factors which determine the type of surface haulage system to be installed.

6(b) Animal Transport

6(b)(i) Mules have been extensively used for surface contour tramming over distances up to 1,200 feet. Relays of mules are used for longer trams. They are mainly used as feeders to mechanical haulages in areas where the tonnages involved do not justify much capital expenditure. The harness is a chest strap supported on saddles attached to draw chains on either side of the animal.

6(b)(ii) A typical mule haulage system is:- length of haul 6,000 feet operated by five spans of two mules in tandem, feeding to one another in each direction at stations 1,200 feet apart. The tonnage handled per shift is 200.

6(b)(iii) In isolated occurrences with very limited tonnages in mountainous country, pack mules have been used economically and effectively.

6(c) Mechanical Tractor Haulage

6(c)(i) A normal petrol driven farm tractor has been adapted to haul spans of 20 trucks over a tramming distance of 6,000 feet. The tractor wheels straddled the 18 inch gauge track with ample clearance. The distance travelled per shift is 22 miles for tonnage handled of 120. The cost per ton/mile is approximately 1 cent. This

type of haulage is suitable as a feeder system for handling medium tonnages from areas with low reserves. It is flexible and little capital is required.

6(d) Electric Tramways

6(d)(i) Overhead trolley locomotives are used for long hauls from areas where track gradients are light. The method is most suitable for collecting tonnages from outlying producing units where sufficient reserves have been proved to justify a fairly high capital expenditure. The locomotives used operate at 500 volts D.C. with a drawbar pull of 2,400 lbs. The tramming speed is 10 miles per hour with a span of 20 hoppers, each with a carrying capacity of 1.6 tons. The running cost including crews and maintenance is 10 cents per ton/mile.

6(d)(ii) Storage battery locos are used over shorter hauls from mines with more limited reserves. The capital cost of the loco is higher but the units are more flexible. This type of loco has a higher maintenance cost and a more limited carrying capacity.

6(e) Road Transport

6(e)(i) With the improvement in road construction over recent years and the working of a number of more isolated deposits, the use of road transport has been extended. The method is most flexible and can be used for limited tonnages from widespread areas or from steady producers well removed from the mill, where tonnages do not justify the erection of a separate reduction plant. A fleet of ten 8-ton Diesels hauled 5-6,000 tons per month over a distance of 13 miles to the central mill. The side-tipping arrangements on the lorries is operated by an overhead winch at the tipping point, thus reducing the purchase price of the vehicle. Heavy road gradients preclude the use of trailers. Elevation differences of over 2,000 feet between loading and delivery points have been encountered. For determining the best route for a haul, profiles of the alternative routes are plotted. An average operating cost per ton/mile is 6 cents.

6(f) Self Acting Gravity Planes

6(f)(i) This simple and cheap method of handling ore down hillsides has been extensively used and has proved most efficient. For inclinations less than 25^{0}, spans of cars or single units are used. For steeper gradients and higher tonnages, bottom dump skips can be used. The type of brakewheel depends on the load and distance of tram. For light loads, the fleeting wheel is mounted horizontally. This wheel and its brake path are cast together. Three turns of the rope round the fleeting wheel are sufficient to prevent brake slip for control of the descending loaded span. With larger loads, double drums are used with heavier brakeing arrangements. One system has proved effective over a distance of 1,500 feet with loads of 5 tons. The capacity is 200 tons per 8 hour shift. Erection, maintenance and operating costs are exceedingly low.

6(g) Aerial Gravity Haulages

6(g)(i) Where the countryside does not lend itself to the laying of tracks due to steepness and irregularities, this type of haulage has proved most reliable and cheap to operate. Two $1\frac{1}{2}$" diameter secondhand winding ropes spread 6 ft. apart are anchored top and bottom

of the slope, and serve as standing ropes. Buckets with a carrying capacity of ½-ton are underslung from a framework carrying the running pulleys. The hauling rope is ½" diameter and has three turns round the brake wheel. It is attached to the framework of the bucket. The performance on an aerial gravity plane with a rope span of 1,800 feet averaged 130 tons per shift with a top rope speed of 1,500 feet per minute. The bucket load is ½-ton.

6(h) Aerial Tramway

6(h)(i) This type of haulage is used for all transport in heavily dissected country where gradients are too heavy for road transport. The capital cost is usually high, requiring the establishment of reasonable reserves before construction. The system used is a bi-cable continuous tramway with fulls and empties travelling in opposite directions on two ⅝" diameter track cables. The capacity is 120 tons on two shifts with ½-ton buckets hauled by a ½" diameter traction rope. The length of the haul is 4,265 ft. with seven supporting towers. Maintenance costs tend to be high, with moderate running costs. The power requirement is usually low as there is a degree of counter-balancing of the full and empty buckets.

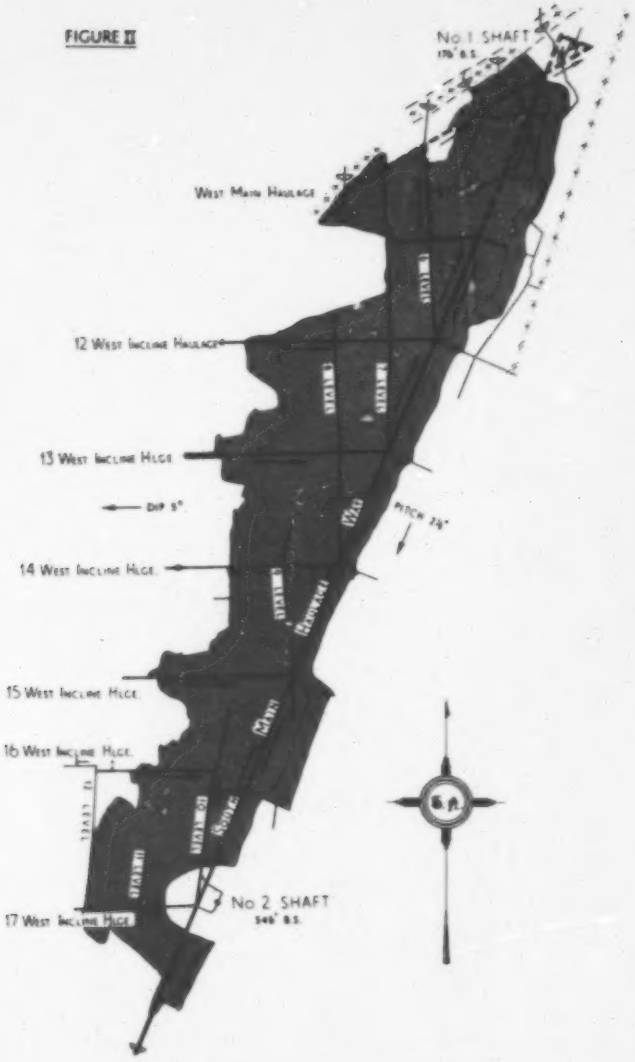
7. POWER GENERATION

7(a) An adequate and reliable power supply is essential for a mechanised mining operation. The type of power supply and size of unit are determined by local conditions, the life of the mine and capital available. A number of units have been assembled of which the largest station is a 1,800 A.W. hydro consisting of three double discharge turbines. In an area of fluctuating seasonal rainfall the necessity for supplementing units during the dry season reduces the advantage of the extremely low operating costs for hydro power. With improved mining prospects a 750 A.W. steam turbine was added. A comparison of the generating costs of the various units in operation is: hydro 0.14 cents/unit steam 0.8 cents, suction gas 2.3 cents and diesels 3.0 cents. All units are phased into a common transmission circuit.

8. CONCLUSION

8(a) The degree to which mechanisation can be economically introduced into a mining operation depends on many factors. The nature of the orebody and the percentage payability will determine the type of equipment which can best be employed and the amount of mechanisation which can be economically adopted. The rate at which a property is to be opened up and the required rate of production are also determining factors. Some details of the extent and size of an orebody and of possible reserves of payable tonnages are required before a mechanisation programme can be fully planned. Efficient utilisation of equipment depends on sound maintenance procedures, maximum operating time and a reliable and adequate power supply. The location of a mine and the regularity of supplies will determine the quantity and range of stocks to be carried. The type and supply of labour and the conditions of employment are also factors which must be considered. Much benefit can be derived from the application of work study to the planning and operation of a mechanisation programme. In small mining operations extensive mechanisation does not always produce the most economic results. Sound judgment is required for the introduction of mechanical equipment which however, when soundly applied, can greatly increase productivity and mining efficiency.

FIGURE II



TRANSVAAL GOLD MINING ESTATES LIMITED.

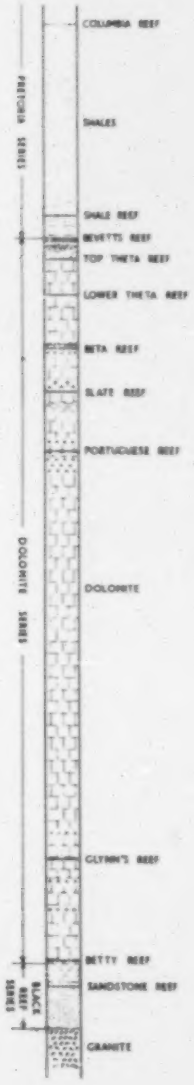
PLAN SHOWING LAYOUT OF UNDERGROUND WORKINGS AT VAALHOEK MINE

LEGEND

STOPED AREAS
REEF DRIVES
HAULAGES (DIVISIBLE ROPE, DOUBLE ROPE, SINGLE TRACK)
DYKES
WATERTIGHT DOORS

FIGURE I

COLUMNAR SECTION



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ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.3.2.2

South Africa

SOME INNOVATIONS TO IMPROVE ESTIMATION OF RIVER FLOW AND DATA COLLECTION

By J.P. KRIEL,
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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

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SOME INNOVATIONS TO IMPROVE ESTIMATION OF RIVER FLOW AND DATA COLLECTION. A.3.2.2.

By J.P. Kriel, J.S. Whitmore, K.J. Harvey, A.L.Rabie, R.de Villiers and D.F. Roberts. Edited by J.P. Kriel.
HYDROLOGY DIVISION, DEPARTMENT OF WATER AFFAIRS, REPUBLIC OF SOUTH AFRICA.

1. Where stream flow records are inadequate estimates often have to be made to assess water resources. This paper deals with some innovations used in the Republic of South Africa to improve the accuracy of data collection as well as the reliability of such estimates.

2. ESTIMATION OF RAINFALL OVER A CATCHMENT (J.S.Whitmore).

a. Inadequate streamflow records can in many cases be supplemented by estimates of flow based on rainfall, but even this solution may be complicated by a dearth of rain gauges in the catchment.

b. Improved methods have been devised for estimating mean rainfall over a catchment in which there are at least some gauges (1). These include a group mean, weighted for the area of zones obtained by a primary altitudinal subdivision of a catchment and a secondary subdivision based on aspect. In another method the area of influence of each station is represented on a map by a polygon based not on the distance between adjacent stations but on the projected altitudinal difference between them. In a third method, plotted stations are linked to form triangles whose area can be calculated from measurements of length, obviating the need for planimetry.

c. Multiple curvilinear regressions can be used profitably to establish the relationship between the mean annual rainfall of stations distributed over a broad area and their positional factors, so that these latter can be used to estimate the mean annual rainfall of any ungauged catchment within the area (2). The linear multiple regression is first determined, whereupon net linear regressions of mean annual rainfall (Y) of each of the independent variates (such as altitude, aspect and continentality) are derived in turn while the remaining independent variables are held constant. Residuals, i.e. differences between actual and calculated Y for each station, are plotted as deviations from the net regression lines to reveal, by successive approximations, the relationships between mean annual rainfall and each positional and site factor. The method is useful as it facilitates comparison of factors which jointly determine the mean annual rainfall at a point. A study of the southern Cape Province of the Republic of South Africa proved continentality to be a dominant influence, the hyperbolic net regression curve showing that mean annual rainfall diminishes rapidly with increasing distance from the sea up to about 100 miles inland whereafter the further decrease is negligible. Altitude emerged as another important control for, independently of its relationship to other factors, mean annual rainfall increases by about 5" per 1,000', but not regularly, the increase being more rapid from 0-1,000', and again between about 2,500' and 4,000' than

for other altitudinal increments; this may be due jointly to the general increase in altitude inland and to a topography comprising a series of mountain ranges parallel to the coast separated by intermontane valleys. The effect of aspect was not so definite but, other site factors being equal, mean annual rainfall on a southerly slope is about 7" more than on a northern slope. Whereas an increasing tendency from west to east was discernible on the mean annual rainfall map, this was scarcely apparant in the net regression curve of mean annual rainfall on longitude, which fluctuated about the horizontal; it was concluded that the apparent easterly increase was in fact a manifestation of interactions between other factors such as altitude and continentality.

d. While an estimate of mean annual runoff from an ungauged catchment can generally be hazarded from an indirect determination of mean annual rainfall (see sub-paragraph c), nothing is revealed of flow fluctuations occasioned by seasonal and annual rainfall variability. One promising solution lies in extracting maximum information from existing rainfall records and in mapping, even in a generalised manner, certain key parameters whose values for any catchment devoid of raingauges may then be read off the maps. Using these data it will often prove possible to construct an annual rainfall record (of any length) which is entirely synthetic but which possesses a frequency distribution and variability appropriate to the locality (3). The basic assumption is that in most regions the frequency of annual rainfall corresponds to a modified "normal distribution". A true "normal distribution" curve is completely defined by the mean of the items and by standard deviation. In the case of annual rainfall, modifications may be caused by skewness and kurtosis, both of which are easily determined. Having used this modified "normal distribution" to compute a synthetic annual rainfall record with a frequency distribution determined from the 4 parameters aforementioned, it remains to arrange the items in appropriate sequence. From probability theory it is easy to calculate the number of runs of wet and dry years, of various lengths which should occur in a random series, and should the locality be characterised by significant "persistence" in annual rainfall or alternatively by a significantly high proportion of short wet or dry spells (4), the distribution of items within the synthetic annual rainfall record can be modified accordingly. As a final refinement the annual record can be broken down into smaller components. Undoubtedly far more information can be extracted from long-term rainfall records than is generally attempted and even if the station network is comparatively sparse the mapped parameters can be widely useful.

3. ESTIMATION OF RUNOFF FROM RAINFALL DATA (J.P.Kriel and K.J.Harvey)

(a) Mean annual runoff figures are very useful as a first step in assessing the potential value of surface water resources. Once they have been established comparisons with the characteristics of similar gauged catchments can supply the information on which to base actual dependable yields.

(b) In 1950 a study of the available streamflow records and rainfall data of the Republic of South Africa was made (5). It was found that the relationship between mean annual runoff and average annual rainfall could be reasonably well represented by the expression $r = KR^n$ where "r" is the Mean Annual Runoff (M.A.R.), "K" a constant, "R" the average annual rainfall, and "n" an exponent which varied between 2 and 5. In view of the lack of data on very small catchments where rainfall is uniform, and the short-term records of which use had to be made in some cases, it was decided to adopt a value of n = 3 for further study of the mean annual runoff for the country as a whole.

(c) The first step in this study was to use all available rainfall records to draw an isohyetal map of rainfall normals on maps which also showed the topography of the country to a scale of 1 : 500,000.
(d) The next step was to compare the M.A.R. per unit area for different catchments with the rainfalls on those catchments. Records from 222 river gauging stations were used. Allowance was made for use of water upstream of the gauging stations. In view of the fact that it had been found that runoff varied approximately as the cube of the rainfall, the weighted average rainfall for each catchment was calculated from the equation

$$R_m = \left(\frac{\Sigma aR^3}{\Sigma a}\right)^{\frac{1}{3}}$$

where R is the average rainfall for each incremental area "a" of the catchment.
(e) The unit M.A.R.'s (i.e. M.A.R. per unit area) were then plotted against the corresponding weighted rainfall figures on logarithmic paper. After prolonged study the different points could be separated into similar groups and mean runoff-rainfall curves established for different regions of the country. Seven runoff zones were established in each of which runoff-rainfall relationships were similar, but these relationships varied appreciably between the different zones. The rainfalls required for different mean annual runoff figures were established and the variation between the different zones is illustrated in Table I, which gives some of the values determined.

TABLE I

Relationship between Mean annual runoff and rainfall for different zones in the Republic of South Africa.

Mean annual runoff, in acre-feet per square mile	Average annual rainfall in inches required to produce the given M.A.R. in each zone.						
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
10	20.0	16.5	-	12.0	10.0	8.7	6.5
100	29.2	27.0	24.8	22.5	20.5	18.3	15.7
1,000	52.5	48.5	47.5	46.0	44.0	42.0	-

(f) By making use of the derived relationships and the rainfall map referred to in subparagraph 3(c), it was possible to plot equal runoff lines and thus to prepare a map showing the mean annual runoff for the Republic of South Africa. Experience since the map was prepared has shown up some weaknesses in it, but in general it has proved to be very useful in making estimates of water resources. Records for a further 15 years are now available, but estimates based on the map are usually well within 20% of runoffs obtained by making use of all the present data. In due course anomalies will be eliminated as more data become available.
(g) As implied in subparagraph 3(a) the determination of mean annual runoff is but a first step in assessing the water resources of a river. Draft curves derived from similar gauged catchments are used to determine assured yields, all curves being plotted in terms of the M.A.R. In various cases efforts have been made to extend records by means of annual or shorter term rainfall-runoff relationships, and although some improvement in accuracy has been obtained, the scatter of results for South African conditions is generally such that greater reliance cannot be placed on such estimates.
4. Sections 2 and 3 of this paper have dealt with methods for

assessing certain aspects of the water resources of rivers where inadequate records exist. Sections 5 and 6, on the other hand, deal with methods to improve the accuracy of data collection.

4. A GAUGING DEVICE FOR SEDIMENT-LADEN STREAMS (A.L.Rabie and R. de Villiers).

a. Sediment-laden streams tend to deposit their load upstream of gauging weirs built across them. This may seriously impair the accuracy of measurement as scour with subsequent re-deposition may take place, leaving no obvious evidence of conditions during a series of floods, so that actual bed levels and cross-sectional areas which may affect flow conditions are unknown. In addition, plant growth tends to establish itself in the saturated sediment deposits, thereby furthering the permanent build-up of sediment layers and clogging up the approaches above weirs, requiring costly maintenance. The high and variable velocity of approach above weirs which is caused by sediment deposits and the resultant vegetation build-up prevents accurate calculation of discharge tables for weirs for which stable stilling ponds or approach channels are required.

b. It is most desirable that the conditions upstream of a weir should be stabilised, that flood debris should pass the structure and that sediment and vegetation build-up be kept to a minimum. At the same time, in order to avoid the necessity of recording readings at different points, the discharge depth should be measured at a single point upstream of the entire measuring structure. A rectangular flume with a level bed, incorporated as a low notch to pass sediment at a gauging weir, was developed with these objects in view. One or more of these flumes with a width of 15 to 20 feet each are flanked by weir notches with crests at considerably higher levels.

c. A model flume with sides adjustable from 1 to 8 feet wide and 5 feet long was used to determine the necessary entrance conditions for smooth flow through the structure. The standard adopted as necessary for stable discharge relationships was that no shock waves should be formed in the flume with free flow. Initially the model had a right-angled entrance. The paths of water filaments flowing round these corners were determined for various depths of flow and flume widths. A study of the curves of these paths showed that they could all be related to a standard curve having two radii dependent on the relationship between the flume width and the water depth. Entrance transitions of these shapes were fitted a and further experiments carried out to determine the limits within which each set of transitions would be effective. It was found that smaller radii than those determined from the initial curves were satisfactory for equivalent depths of flow through the flume, but that there is a definite relationship between the entrance radii, the flume width, and the depth up to which smooth flow can be maintained through the flume.

d. The length of the flume excluding entrance transition, should be such that stable flow conditions are obtained within the flume. The experiments indicated that this required that the uniform rectangular portion of the flume should have a length of 4H, where H is the head as measured upstream of the entrance.

e. The shape of flume finally adopted is shown in FIGURE I. In FIGURE II is shown a dimensionless plot connecting the flume entrance radius R, the flume width B and the upstream depth H above the flume sill level. The curves indicate the zone for which satisfactory smooth flow conditions can be expected, a transition zone in which flow conditions are uncertain and a zone in which shock waves are likely to occur. With further study it is hoped to reduce the zone of uncertainty but the curves can be used for design as they are.

f. Flumes were calibrated by means of measurements on the model as well as by means of full-scale field measurements. It was found that downe stream water depths up to about 0.6H above the flume bed did not affect discharges. The flume can, however also be used as a measuring device with higher submergenves.
g. One installation with two flumes has been in operation in a sandy river for nearly two years, and so far the flumes have been effective in preventing accumulations of sediment upstream of the weir. Previously sand was deposited up to the weir crest.

5. AN IMPROVED METHOD FOR CALCULATING FLOOD PEAK DISCHARGES FROM SLOPE-AREA MEASUREMENTS (J.P.Kriel).

a. Flood peaks often cannot be gauged directly because of the short duration and irregular occurrence of spates. Frequently the best that can be done is to obtain levels from flood marks after the event, but flood peak calculations based on such data are subject to large errors, particularly due to the arbitrary choice of a roughness coefficient to be used in the calculations. In view of these considerations a method for calculating the flood peaks from water surface level data and river cross-sections has been developed which eliminates the arbitrary selection of the roughness coefficient. For applying this method at least three, but preferably four or more cross-sections with flood levels at them must be available, the friction coefficient over the reach of the river considered must be sensibly constant and the cross-sectional areas of the water prism must not all be equal.
b. By making use of the Manning formula for friction loss in open channels and the Bernouilli theorem, the discharge flowing between sections 1 and 2 in a river channel can be expressed by the equation

$$Q^2 = \frac{Z_1 - Z_2}{\frac{n^2}{8.833}\left(\frac{1}{A_1} + \frac{1}{A_2}\right)^2 \frac{L}{(R_m)^{4/3}} + \frac{a}{2g}\left(\frac{1}{A_2^2} - \frac{1}{A_1^2}\right) + \frac{a\,k}{2g}\left(\frac{1}{A_1^2} - \frac{1}{A_2^2}\right)}$$

where Q = discharge in cusecs
n = roughness coefficient in Manning formula $V = \frac{1.486}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$
Z_1 & Z_2 = Water surface levels at sections 1 and 2 respectively.
A_1 & A_2 = Cross-sectional areas of water prisms at 1 and 2 respectively.
L = Length of river channel between sections 1 and 2.
R_m = Mean hydraulic radius for two sections.
a = Velocity distribution coefficient for kinetic energy. For natural channels this probably varies between 1.1 and 1.5(6).
k = Turbulence loss coefficient. For accelerating flow this may be taken as zero, but for expanding flow(i.e. velocity decreasing downstream) a value of 0.25 would probably be applicable where the enlargement of channel is gradual.

For a given reach of river in which flood levels and the cross-sections have been surveyed it will be noted that there are two unknowns in the equation, viz. the discharge "Q" and the value of the Manning coefficient "n", if it is assumed that the coefficients "a" and "k" can be determined with sufficient accuracy. Normally a is taken as unity in river hydraulics calculations, but it has been found that its correct value is of some importance for flood peak calculations. If the data for three cross-sections were known, a similar equation could be written between

sections 2 and 3, and with two equations it should be possible to solve for the two unknowns Q and n. Usually this is not possible however, for in picking up flood levels it is never possible to obtain exact water surface elevations. If exact water surface elevations are not used in the equations, the solution of them will yield imaginary values. Hence some adjustment of water levels to comply with the energy relationships on which the equations are based is necessary.

c. The procedure followed to overcome the difficulties encountered in solving the equation is as follows :

(i) Determine the most probable water levels at the sections and calculate the water areas and hydraulic radii.

(ii) By making use of equation calculate a curve of Q against n for each pair of sections such as 1 and 2, 2 and 3, as well as 3 and 4 if available, as shown in FIGURE III. If all water levels are correct these curves should intersect in one point. It will be seen from FIGURE I however, that the curves give three different intersections, and hence three different values of Q and n.

(iii) Decide on the two most reliable water levels at sections. Usually these can be taken at the first and last sections in the reach as this will yield the lowest probable percentage error due to the large overall drop in water surface. By assuming a mean value of Q and n as indicated by the intersections in FIGURE I, calculate the values $Z_1 - Z_2$, $Z_2 - Z_3$ and $Z_3 - Z_4$. The sum of these three calculated values should then equal $Z_1 - Z_4$ if Z_1 and Z_4 are accepted as correct. In general the sum will differ from the correct value, and the individual terms must be adjusted proportionally to yield adjusted values of Z_2 and Z_3.

(iv) Revised cross-sectional areas and hydraulic radii are then determined to correspond with the adjusted values Z_2^1 and Z_3^1 and the procedure outlined in subparagraphs (c)(ii) and (iii) repeated. The result of such an adjustment is shown in FIGURE IV, where it will be seen that the intersections have converged considerably. Systematic tabular calculations greatly simplify the method.

v. In many cases further adjustments will be necessary before the curves will intersect in one point. In the case illustrated here the values finally found were Q = 34,000 cusecs and n = .040.

(d) In a number of analyses to date it has been found that the effect of "k" on the discharge Q is usually small, but that the effect of variation in the kinetic velocity distribution coefficient α may be as large as 25%. Studies are planned to assist in assessing the value of this coefficient with greater accuracy.

(e) A complete discussion of the application of this method is not possible here. It has been expanded and applied to take account of composite channels where rivers overflow their banks. It has proved to be very useful to obtain reasonably satisfactory flood peak estimates where no other means could be used. In three cases where the results could be checked the figures obtained from rated stations were within 5% of the calculated values for two of the rivers and within 20% for the third. Even the worst case is equivalent to guessing the value of "n" within 20%, which usually is not practicable.

6. THE DETERMINATION OF THE MAGNITUDE-FREQUENCY RELATIONSHIP OF ANNUAL FLOOD PEAKS IN SOUTH AFRICA.(D.F. Roberts).

(a) While the use of unit hydrographs is advisable for important structures flood peak probability data are usually of great assistance. An empirical study was recently made to find a simple method of plotting the data on semi-logarithmic paper so that the mean line representing the magnitude-frequency relationship could be extended to estimate the

magnitude of a peak with a return period greater than the length of the record.

(b) The problem was to find some function of "n" the number of observations, and of "m" the rank of the m^{th} largest observation (the observations being arranged in descending order of magnitude) so that when plotted the points would be scattered about a straight line which could be fitted and extended mathematically with confidence.

(c) It was realised that individual records could not be used to determine this function since they are only small samples from the large population of flood peaks. It was therefore decided to combine twenty records of thirty five years duration, by standardising the observations and calculating the mean of each group of twenty standardised values corresponding to each value of "m". (Note that the standardised value Z_m is equal to $\frac{Xm - \bar{X}}{Sx}$ where Xm is the m^{th} largest flood peak and $\bar{X}$ and Sx are the mean and standard deviation of the n observed annual peaks).

d. These mean values of Zm form a composite sample of thirty five terms which provide a very good picture of the magnitude-frequency distribution of the parent population.

(e). The composite sample did not produce a straight line when plotted according to the "California Method" (7) in which the plotting position is represented by $T = {}^{n}/_{m}$, nor was the "Geological Survey Method" (8) where $T = \frac{n+1}{m}$ any better, while the "Gumbel Method" (9) proved to be the poorest, so that none of the methods provided a straight line that could be extended with accuracy. A straight line was produced by using the function $T = \frac{n+1}{m} + c$, the best value of c (=0.84) being found by trial and error, first graphically and then mathematically.

(f) The "Hazen function" ($T = \frac{zn}{zm-1}$) (7) produced a still better fit in that the standard error of estimate was lower and the points better distributed about the straight line, the regression equation being $Zm = 1.014 \log e \left(\frac{zn}{zm-1}\right) - 1.004 \pm 0.28$ which for the maximum peak, (m = 1.0) leads to $\frac{Xn - \bar{X}}{Sx} = 1.014 \log e\,(SN) - 1.004 \pm .028$ where Xn is the most probable maximum flood peak in a period of N years.

(g) This equation is theoretically applicable only when $\bar{X}$ and Sx are the mean and standard deviation of the observations in a thirty five year record. For other lengths of record the values of the coefficients would vary but the change would be negligible compared with the average standard error of the mean which in South Africa varies by ten to twenty percent. In view of this variation the following approximations are used without any serious error.

a. When the return period N is equal to or less than n, since

$$N = {}^{n}/_{m}\,, \quad XN = \bar{X} + Sx\left(\log e \frac{N}{1 - \frac{N}{zn}} - 1\right)$$

b. When the return period N is equal to or greater than n

$$XN = \bar{X} + Sx\,(\log e\, 2N - 1)\ldots$$

(h) Before calculating the mean and standard deviation of a record the maximum peak should be carefully scrutinised and if it appears to be a misfit its value should be adjusted to bring it into line with the rest of the data.

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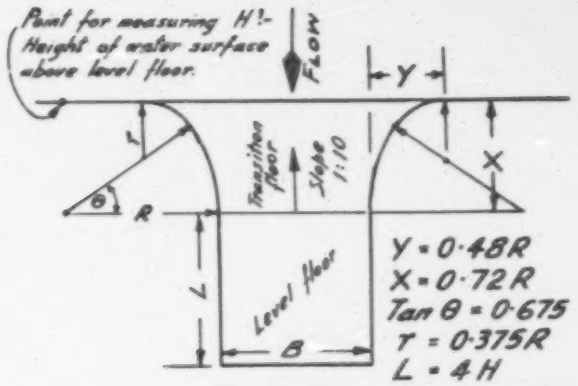

FIG. I. Plan of rectangular flume used in weirs in Silt-laden rivers.

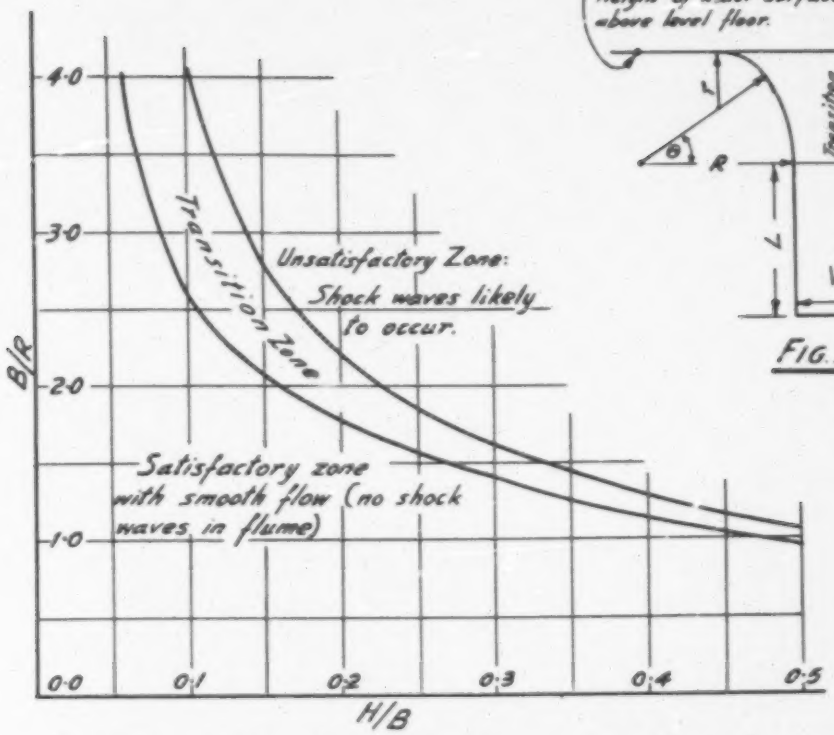

FIG. II Curves for designing entrance to rectangular flume shown in Figure I.

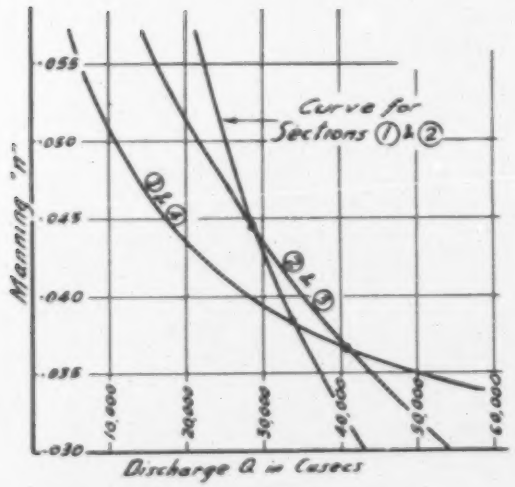

FIGURE III. Initial curves.

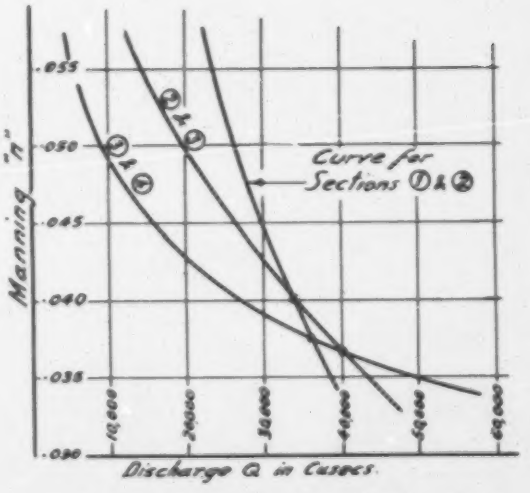

FIGURE IV. Curves after first adjustment.

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DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES

Point de l'ordre du jour : A.2

France

ACTIONS COMPLEMENTAIRES NECESSAIRES AU DEVELOPPEMENT INTEGRE DES BASSINS HYDROGRAPHIQUES

Par Paul BOURRIERES,
Ingénieur général des Travaux Publics
Directeur général du Bureau Central d'Etudes
pour les Equipements d'Outre-Mer

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

NOTES

1. Les mémoires choisis pour être présentés en séance générale pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

2. Les mémoires choisis pour être présentés en séance spéciale pourront être obtenus à la Conférence dans l'une seulement de ces langues officielles.

3. Les résumés qui ont été rédigés pour tous les mémoires par les auteurs de ceux-ci pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

4. Préalablement à la Conférence, les mémoires et les résumés ne feront pas l'objet d'une distribution générale mais d'un tirage restreint destiné aux délégations des gouvernements et autres participants officiels. La publication et la distribution générale des actes de la Conférence s'effectueront conformément aux règles et pratiques agréées par le Comité des publications des Nations Unies.

CONFERENCE SCIENTIFIQUE DES NATIONS UNIES
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A.2 - ACTIONS COMPLEMENTAIRES NECESSAIRES AU DEVELOPPEMENT INTEGRE DES BASSINS HYDROGRAPHIQUES

Mémoire de M. Paul BOURRIERES

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1 - RAPPEL SUR LE DEVELOPPEMENT INTEGRE DES BASSINS FLUVIAUX AU SENS CLASSIQUE

Deux publications des Nations Unies font un exposé des procédés à employer pour l'étude du développement intégré des bassins fluviaux.

Il s'agit en particulier de la publication de la Commission Economique pour l'Asie et l'Extrême Orient intitulée : "Multiple Purpose River Basin Development Part 1 - Manual of River Basin Planning Flood Control Series n° 7" parue en 1955 et du "Développement intégré des bassins fluviaux" rapport présenté aux Nations Unies en 1958 par un collège d'experts composé de MM. Mohsin Ali, Jean Aubert, Arthur E. Griffin, Sir Murdoch Mac Donald and Partners, MM. Carlos Lleras Restrepo, Egbert de Vries, Gilbert F. White et M. Vassily V. Zvonkov.

2 - INSUFFISANCE DES DEBOUCHES ECONOMIQUES EN PAYS PEU DEVELOPPES

Voulant rester parfaitement objectifs, ces rapports ne visent pas à modifier le contexte économique et technique dans lequel s'insère le programme de développement du bassin fluvial. Ils se bornent à examiner quelles sont les données économiques, techniques et sociales à rassembler, et attirent l'attention sur le fait que les débouchés économiques et sociaux doivent être à la hauteur des sacrifices consentis.

Dans bien des cas, cet examen des débouchés économiques est décevant dans les pays peu développés, qui cependant mettent beaucoup d'espoir dans les grands travaux hydrauliques.

3 - CREATION DES DEBOUCHES EN PAYS PEU DEVELOPPES

L'objet du présent rapport est d'orienter les efforts de ceux qui ne se contentent pas de renoncer à un travail en voyant qu'il est difficile, et qui désirent au contraire consentir les efforts complémentaires pour obtenir le plein succès d'un travail partiel.

Très grossièrement, la proposition est la suivante :

Puisque les travaux hydrauliques, même intégrés, risquent de souffrir d'un manque de débouchés, il faut simultanément développer ces débouchés par un certain nombre d'actions complémentaires.

3.1 - Augmentation des rendements agricoles

Etant donné l'importance particulière que présente l'agriculture dans l'économie des pays peu développés, et étant donné le retard technique et économique que présente souvent cette agriculture, il est très important d'augmenter les rendements par un certain nombre d'actions complémentaires à l'hydraulique.

Si le rendement est déjà doublé par l'apport d'eau et qu'il est encore doublé par les améliorations qui sont classiques en matière de culture sèche, ceci revient à quadrupler les rendements primitifs. Par conséquent, le coût des ouvrages hydrauliques plus le coût des actions complémentaires sera amorti sur trois fois la production primitive, tandis que l'action hydraulique ou l'action de culture sèche isolées n'auraient pu être amorties que sur une fois la production primitive.

Il faut donc résolument abandonner l'opposition traditionnelle entre les partisans de la culture sèche et partisans de la culture irriguée, et consentir dans les périmètres irrigués toutes les actions complémentaires qui sont consenties pour la culture sèche. Il faut même les consentir par priorité dans ces périmètres. Si les actions de développement de culture sèche accroissent fortement les effets de l'irrigation, la réciproque est vraie, et l'apport d'eau améliore de façon énorme les efforts en culture sèche.

Les principales actions complémentaires dans le domaine agricole portent sur l'apport d'engrais, le choix des variétés, les façons culturales, la formation professionnelle et l'encadrement.

Il est bien connu que les engrais peuvent augmenter de façon considérable le rendement des terres, mais à deux conditions : la première est qu'une quantité d'eau suffisante permette à ces engrais d'être assimilés par les plantes, la deuxième c'est que les populations rurales aient un niveau de vie suffisant pour pouvoir consentir l'effort financier que représente l'achat des engrais ou l'élevage du bétail.

Il est bien connu en effet que les populations très pauvres ne peuvent pas pour des raisons d'ordre économique, développer l'emploi des engrais, même s'il s'agit de fumure naturelle.

Le choix des variétés et les progrès agronomiques proprement dits sont essentiels au fort rendement, et il faudra d'ailleurs se garder de transporter purement et simplement les variétés qui ont donné des résultats favorables en culture sèche, pour les utiliser en culture irriguée. Les stations d'essai et de vulgarisation auront un rôle essentiel.

Les façons culturales elles-mêmes devront être profondément modifiées. On ne peut pas en périmètre irrigué maintenir le système des jachères et il y a lieu de les remplacer par des assolements. Les labours devront être adaptés à la transformation de la terre, et aux exigences des variétés à haut rendement.

En outre, et c'est peut-être là l'effort complémentaire le plus important, l'aménagement de périmètres irrigués devra être accompagné d'un effort, très important et long, de formation professionnelle des agriculteurs. Cet effort de formation devra être complété par un encadrement technique et peut-être commercial, sur le lieu même du travail. Il a pour objet le conseil permanent des agriculteurs, leur maintien en haleine, et également l'information des échelons supérieurs de l'administration sur les problèmes qui se posent au niveau de base.

3.2 - Eau potable et électrification locale

Nous avons groupé sous un même paragraphe la consommation de l'eau potable et celle de l'électricité domestique, en raison des liens étroits qui existent entre ce type de consommation et le niveau de vie individuel.

Comme nous l'avons dit, le taux de consommation est beaucoup plus bas dans les pays peu développés que dans les pays riches.

Pour l'eau par exemple, la consommation des communes rurales pauvres peut être inférieure à 20 litres par habitant, tandis que dans les grandes métropoles industrialisées, elle dépasse le plus souvent 500 litres.

Au point de vue énergétique, la consommation en pays rural pauvre est après établissement d'un réseau de distribution, de quelques kilowatts/heure par personne et par an, alors qu'elle est de plusieurs milliers dans les pays industrialisés. Or, le rapport des revenus varie entre 40 dollars par an dans les pays les plus pauvres, et 2.000 dollars par an dans les pays les plus riches.

Il apparaît donc que la consommation locale ne pourra se développer qu'en fonction du développement des activités de toutes natures de la population et qu'elle se développera d'ailleurs plus vite.

3.21 - Développement de la petite industrie

Parmi ces activités, la petite industrie est particulièrement intéressante car outre son effet direct de consommation de l'énergie (très supérieure au point de vue régularité à celle de l'éclairage), la petite industrie est en elle-même une source de relèvement du niveau de vie, et comporte en particulier des prolongements avec effets multiplicateurs considérables, résultant des échanges de monnaie.

Cependant, qu'il s'agisse de la consommation domestique proprement dite ou de la consommation dans les petites industries, il faut bien savoir que l'extrême diversité des actions à mener, l'insuffisance des cadres et l'insuffisance de capital privé, limitent la cadence de développement. Par conséquent, les chiffres relatifs à la rentabilité des ouvrages hydrauliques, doivent tenir compte à la fois de la situation actuelle et d'un taux de développement évalué raisonnablement, compte tenu de l'ensemble des autres actions décidées.

Il arrive que ce taux soit très rapide, allant jusqu'à assurer le doublement en trois ou quatre ans pendant quelques années. Mais il serait tout à fait déraisonnable d'envisager une multiplication par 10 ou par 100 dans des délais de même ordre, surtout si on compte sur un développement spontané qui est beaucoup plus long. En moyenne on double en 7 ou 8 ans.

3.3 - Industries grosses consommatrices d'énergie

Si le développement de la consommation domestique est lent mais sûr, celui des grandes industries peut être au contraire très rapide, mais aléatoire et exige de façon impérative un certain nombre de circonstances favorables, dont certaines sont naturelles (et il faut les découvrir) et d'autres sont artificielles (et il faut les réaliser).

3.31 - Recherche géologique et minière

Parmi les circonstances favorables à la réalisation d'industries spécialisées, grosses consommatrices d'énergie, figure l'existence de minéraux transformables : bauxite pour l'aluminium, phosphate et sulfate pour l'industrie des engrais, minerais convenables pour les métaux non ferreux, etc...

Dans les pays peu développés, on n'a eu le plus souvent dans le passé, ni le temps, ni les moyens d'effectuer une recherche géologique et minière systématique, qui est d'ailleurs extrêmement onéreuse.

Lorsqu'on envisage de dépenser des centaines de millions de dollars dans des actions hydrauliques, il serait absurde de ne pas consentir les quelques millions de dollars que représente la recherche géologique et minière, dont les résultats favorables peuvent transformer complètement les conditions de rentabilité des grands ouvrages.

On peut d'ailleurs dire statistiquement qu'aucune recherche géologique et minière s'étendant sur de grandes surfaces et menée avec de grands moyens, n'est stérile.

Si les résultats sont négatifs en ce qui concerne les minéraux qu'on cherchait, susceptibles d'être traités par voie électrique, il restera toujours pour le bénéfice des découvertes d'autre nature, portant sur des minerais de fer, de charbon, du pétrole, des métaux rares, ou d'autres richesses.

Ce qu'il est indispensable de savoir c'est que cette recherche est longue et coûte fort cher. Il ne faut donc pas que son coût empêche de l'entreprendre de bonne heure.

3.32 - Autres matières premières

Les ressources minérales ne sont pas les seules qui puissent être à l'origine de grosses industries consommatrices d'énergie.

L'inventaire forestier portant à la fois sur les espèces et sur leur distribution plus ou moins grande dans la forêt, est une des recherches à conduire.

L'inventaire des ressources agricoles susceptibles de transformation industrielle : distilleries, papeteries, textiles, doit être également fait, et des mesures de développement correspondantes doivent être prises.

L'eau de mer et des lacs salés peut être l'objet d'une industrie chimique intéressante.

3.33 - Main d'oeuvre, qualité et quantité

La quantité de personnes disponibles peut être considérée en première approximation comme une donnée peu variable, sauf s'il y a à proximité des réservoirs de main d'oeuvre importants. Par contre, un effort considérable doit être fait dans le domaine de la formation professionnelle si l'on veut que les industries, grosses consommatrices d'énergie, se développent de façon durable.

3.34 - Prix et débouchés

De même qu'on est amené à envisager des actions à caractère agricole et industriel pour assurer des débouchés à l'eau et à l'énergie, de même il est indispensable d'étudier et de favoriser les débouchés pour les industries consommatrices d'énergie.

Ces débouchés sont de deux natures profondément différentes.

D'abord un débouché local où les prix ne sont pas imposés de façon rigide, mais où la quantité consommée sera généralement faible et en tout cas ne sera pas susceptible de varier très rapidement avec le temps.

Au contraire, le débouché à l'exportation, qu'il s'agisse de pays voisins ou de pays lointains, sera très exigeant sur les prix, qu'il faudra donc limiter de façon très sévère, au besoin en donnant des facilités aux industriels, mais ce débouché à l'exportation présente le gros intérêt d'être susceptible d'un développement très rapide si les prix sont compétitifs.

3.4 - Transports

Certes, tous les auteurs de projets de développement intégré de bassins fluviaux insistent sur le développement de la navigation à la fois pour les transports de pondéreux à longue distance et pour le ramassage par canots et embarcations de petite dimension dans les zones irriguées, mais il faut résolument s'attaquer au problème des transports sous tous ses aspects, et pas seulement sous celui de la navigation.

L'objectif économique recherché n'est pas d'utiliser à tout prix l'eau comme moyen de transport, mais de permettre le développement des activités agricoles ou industrielles résultant de l'aménagement hydraulique, en résolvant les problèmes de transport que soulèvent ces activités.

Il faudra donc traiter à la fois 1°/ les problèmes de liaisons et d'échanges de personnes entre les centres productifs, les centres consommateurs, et les centres animateurs, 2°/ le problème du rassemblement des produits agricoles depuis les exploitations, et de la diffusion des produits industriels jusqu'à ces exploitations, 3°/ les problèmes des transports à distance depuis les zones de production jusqu'aux zones de consommation.

En pays peu développés, l'effort devra porter à la fois sur les pistes légères, les grandes routes, l'aviation, et éventuellement les chemins de fer et les voies navigables.

Une des raisons pour lesquelles on se doit d'être très objectif sur les tonnages à transporter à diverses échéances, est que si la voie d'eau est généralement la plus économique lorsqu'elle a des caractéristiques très larges et que les trafics prévus se chiffrent par millions ou par dizaines de millions de tonnes, il existe des solutions économiquement plus favorables par la voie ferrée, la route ou l'aviation, lorsque les tonnages sont plus petits.

Il faut donc de façon très précise évaluer quels sont les différents tonnages qu'on peut attendre pour diverses importances d'efforts dans les domaines agricoles et industriels.

3.5 - Développement de la pêche

Une première réaction des défenseurs de la nature, est de faire des objections aux aménagements hydrauliques, au nom de la protection des poissons et des industries de la pêche.

C'est un aspect de la question qu'il ne faut pas négliger, mais il faut se garder d'avoir en la matière un esprit purement négatif, et il faut savoir que, si les ouvrages hydrauliques gênent la vie des poissons par la constitution d'obstacles à leur migration, ils peuvent aussi favoriser la vie aquatique dans des proportions énormes par le maintien en eau de grandes surfaces à la saison sèche, et par la possibilité de développer les étangs et les canaux.

Loin d'être un obstacle à l'aménagement hydraulique, le développement de la pêche doit être l'un des objectifs de ce développement, et il constitue l'un de ses débouchés économiques, à la fois directement par une meilleure alimentation des populations, et indirectement.

4 - INTEGRATION A UN PLAN GENERAL DE DEVELOPPEMENT ECONOMIQUE

Toutes les considérations que nous avons exposées plus haut conduisent à la conclusion que, s'il est quelquefois admissible, dans un pays économiquement très développé, de mener une action de mise en valeur des ressources hydrauliques en prenant soin de coordonner ses différents aspects pour une meilleure utilisation de l'eau, une telle coordination n'est pas suffisante dans le cas des pays peu développés. La confrontation de l'état actuel des débouchés économiques et du coût des ouvrages conduirait souvent à considérer ces ouvrages comme non rentables, et à ne pas les réaliser.

La seule façon d'assurer une meilleure rentabilité consiste à créer les débouchés pour l'eau et pour l'énergie, en même temps que l'on met en valeur les ressources correspondantes.

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